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# The Barriers To Adopting Composting Toilets Into Use In Urban And Suburban Locations In The United States

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# THE BARRIERS TO ADOPTING COMPOSTING TOILETS INTO USE IN URBAN AND SUBURBAN LOCATIONS IN THE UNITED STATES

A Thesis

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by

Julia Branstrator

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To the years traveling and those I traveled with.

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# ABBREVIATION

Composting Toilet = CT

# ABSTRACT

Branstrator, Julia M.S., Purdue University, December 2014. The Barriers to Adopting Composting Toilets into Use in Urban and Suburban Locations in the United States. Major Professor: Kathryne Newton.

The amount of fresh water available in the world is a finite resource. Large quantities of the fresh water are located in remote locations, while more accessible sources of fresh water are disproportionately distributed around the world. Some populations lack reliable access to clean water for daily life, making the routine use of potable water in toilets of upper-income countries a questionable practice in terms of resource responsibility, energy use, and sustainable infrastructure. The innovative nature of composting toilets offers potential solutions to the downfalls of conventional, waterborne toilets. However, the path to adoption of composting toilets has encountered barriers of different types, impeding further development of a more acceptable system. This study identifies current barriers to the adoption of composting toilets into use in urban and suburban locations in the United States. A purposeful sample of knowledgeable stakeholders in the industry of composting toilets was contacted for open-ended, semi-structured interviews to collect data. The interviews explored four major discussion topics; the perceptions of stakeholders of barriers to the adoption of composting toilets, the barriers in urban and suburban locations, the differences and similarities between the location types, and what project experiences of the stakeholders had taught them about the adoption process. Twelve barriers to adoption were determined, with seven of these barriers discussed in depth due to their perception by stakeholders as the most problematic, yet effective in encouraging adoption if overcome.

# CHAPTER 1. INTRODUCTION

The purpose of this chapter is to present the guidelines about the proposed study on composting toilets to be undertaken. Included in this work is the statement of the problem, the research questions, the significance of the study, parameters to guide this study and a small number of definitions needed in order to understand the material.

## 1.1 Statement of the Problem

The availability of clean water to the world population has proven to be a continuous struggle. In the 2009 World Water Development Report, Kochiro Matsuura, the Director-General of the United Nations Educations, Scientific and Cultural Organization (UNESCO) has discussed the conflict of the necessity of water to every-day living, and the ways in which water is regulated, used, and viewed the international society:

> "Despite the vital importance of water to all aspects of human life, the sector has been plagued by a chronic lack of political support, poor governance and underinvestment. As a result, hundreds of millions of people around the world remain trapped in poverty and ill health and exposed to the risks of water-related disasters, environmental degradation and even political instability and conflict (World Water Assessment Programme, 2009)."

With populations around the world lacking access to clean water to maintain a safe quality of life, the routine use of fresh, potable water in toilets of upper-income countries, such as the United States, deserves investigation. The conventional style of moving human excrete from a toilet to a waste treatment plant will not sustainably serve as the most commonly used form of waste collection and treatment. “This ’waste’ is collected centrally in sewer pipes by using centrally provided potable quality water as the transport medium. One person produces about 1.02.5 L of urine and 120400 g of feces per day (Rauch, Brockmann, Peters, Larsen, & Gujer, 2003; Schouw, Danteravanich, Mosbaek, & Tjell, 2002) and for each liter of urine passed, the centralized system uses about 615 times of water for flushing it.” “A toilets importance in a residential building is reflected in the amount of indoor water used for flushing; roughly 45100 L per capita per day, or 27% of the water used indoor on a daily basis (Gleick, 1996; Mayer & William, 1999).” In places with more people such as educational and office buildings this percentage is likely higher since toilets and sinks account for the main use of water (Anand & Apul, 2011). With water demand increasing at twice the rate of population growth, technologies to promote sustainable use of water are necessary.

The use of fresh water to move human waste requires a large infrastructure in order to service large, dense populations as well as sparse, rural populations where possible. This large network leads to problems regarding cost, water loss, and energy use. The infrastructure used with conventional, water-borne toilets requires pipes, which over time tend to break and cause leaks. “Many drinking water systems lose as much as 20% of their treated potable quality water due to leaks in their pipe networks (Mehta, 2009).” In 2004, 850 billion gallons of untreated wastewater and storm water were released as combined sewer overflows and between 3 billion and 10 billion gallons of untreated wastewater form sanitary sewer overflows are released each year into the U.S. (United States Environmental Protection Agency (US EPA), 2004). In reference to the required energy of the current system, water and wastewater treatment systems account for approximately 3% of the entire U.S. energy demand (Electrical Power Research Institute (EPRI), 2002).

Along with efficient use of water, there is a needed change of perspective in societies around the world in being personally responsible for waste individuals create in a sustainable fashion. Through history, the further a person is from the waste they create has led to proper hygiene standards as well. A lifestyle that allows separation from waste is an indication of social and economic welfare. However, society has reached a point of having little personal responsibility for the waste it creates. To counteract the damage created and lessen the harmful environmental impacts in the future, society must work with government, business and civil society leaders to adopt sustainable, innovative technology such as the composting toilet to greater use in urban and suburban locations in the US. Many barriers exist in the process of technology adoption, especially in the industry of waste management and water treatment. The innovative nature of composting toilets offers energy efficiency, sustainable collection, and treatment of waste. However, the process of adoption has met barriers of different types, impeding the development of a system able to be accepted by the United States.

The purpose of this thesis was to identify current barriers to the adoption of composting toilets and use in urban and suburban locations. Understanding these barriers may contribute to a great acceptance of composting toilets in a social and political environment, therefore conserving potable water. The use of a composting toilet in place of a conventional toilet in public locations is one solution to using less potable water on a greater scale. Composting toilets are offered in different styles to accommodate different usage styles and have been used successfully in private and public locations throughout history. On a scale of resources and compatibility with the environment, composting toilets suggest a viable aid in the global water crisis. An investigation of the reasons behind composting toilets only being used in rare occasions in public locations will help to illuminate the barriers between greater use and the current taboo nature associated with composting toilets.

1.2 Research Question

What are the barriers to adopting composting toilets into use in urban and suburban locations in the United States?

1.3 Significance of Study

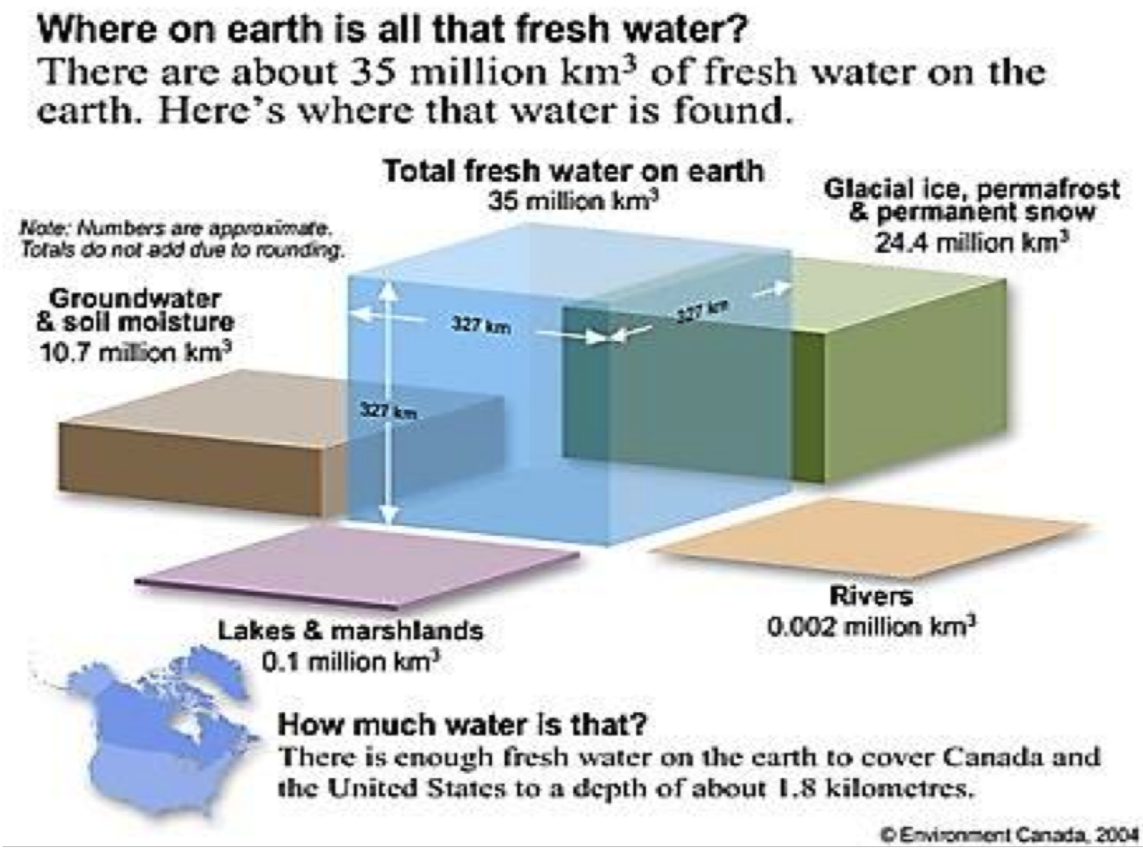


Figure 1.1. Fresh Water on Earth (Environment Canada, 2009)

The amount of fresh water in the world stands as a finite source that must be consciously used at all times. Fresh, consumable water available to the global population is surprisingly low compared to our planet being comprised mostly of water. "The total amount of water in the world is approximately 1.4 billion km3, of which 97.5% is saltwater and 2.5% is fresh water (Gleick et al., 2011)." On top of the limited availability of fresh water, water that is accessible to humans is an even smaller portion of the 2.5% of fresh water on the planet. In contrast to the low volume of easily access fresh water, the number of people around the world left without guaranteed access to clean water for consumption and hygiene is alarmingly high. The location of the human population around the world and the ability to distribute fresh water limits the ability to provide adequate water all.

With this knowledge of limited water, global efforts have been made to conserve water and to bring access to clean drinking water to people in need. Thanks to global action, "over 2 billion people gained access to improved water sources and 1.8 billion people gained access to improved sanitation facilities between 1990 and 2010 (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2012)." However, with population increase in many countries and climate change effecting habitats and lowering water tables, "over 780 million people are still without access to improved sources of drinking water and 2.5 billion lack improved sanitation. If current trends continue, these numbers will remain dangerously high in 2015: 605 million people will be without an improved drinking water source and 2.4 billion people will lack access to improved sanitation facilities (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2012)." These benchmarks are a part of the Millennium Development Goals (MDGs) pursued by the World Health Organization and the United Nation Childrens Fund. The progress made in reaching the MDG in certain aspects shows the ability to increase quality of life for others and for improvement.

The need for water to be used efficiently on a global scale is evident. When looking at the daily habits of upper-income countries with little risk of going a day without fresh water and comparing these habits to those without guaranteed access to water, it shows that some routines would benefit others were they to be made more efficient and sustainable. Society has grown accustomed to flushing away waste, sending it in a medium of fresh water for others to take care of at a waste treatment plant. This cultural practice is a stark contrast to the struggle of societies unable to access a resource that others readily defecate into.

## 1.4 Scope

This research will analyze the barriers currently experienced that make the adoption of composting toilets in urban and suburban locations within the United States difficult. This thesis will provide literature on the use of composting toilets to understand their basics in design and process, past project success and failures, and the variables that have caused barriers between composting toilets and their use in these areas. Barriers determined in past research have been found in different countries with different methodologies that provide a scale of comparison for use within the United States. This research will explore barriers experienced in the United States by conducting semi-constructed interviews with a group of stakeholders in the field of composting toilets; service providers, researchers, authors, and regulators, project leaders and opinion leaders.

## 1.5 Assumptions

The assumptions for this research are factors somewhat out of the researchers control that are central to the thesis and should be addressed.

- The population to be used will be chosen from a pool of stakeholders who will be determined by their role in research, installation, construction, implementation or use of composting toilets.
- The roles of the stakeholders in the use of composting toilets will provide valid input on the field of composting toilets.
- Responses collected will not be tailored in a way to fit a desired outcome.

## 1.6 Delimitions

The delimitations of this study define the boundaries of the study

- This study will not work with hands on equipment for composting toilets.
- This research will collect national data from international stakeholders. The stakeholders will provide data referencing the United States due to its large consumption of water and hesitance to use alternatives to waterborne toilets on a national scale.

## 1.7 Limitations

The limitations of this study list the weaknesses to the study due to factors out of the researchers control.

- Responses from those in the field may be dishonest. Anonymity in summary findings will be kept to allow honest responses without judgment of any single name or business.
- Participation is voluntary, which decreases control in even distribution regarding types of stakeholders.

## 1.8 Definitions

The following are terms with specific definitions that will be used in this report:

- **Biosolid** - "A primarily organic solid product produced by wastewater treatment processes that can be beneficially recycle (United States Environmental Protection Agency (US EPA), 1999)."
- **Composting** - "The biological decomposition and stabilization of organic substrates under conditions that allow development of thermophilic

temperatures as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land (Haug, 1993)."

- **Humus** - "The stable fractions which remain in soil after separation of organic residues are generally known as 'humified material', or 'humus'. Humic substances include numerous poorly identified components which are defined on the basis of fractionation methods (Andreux, Cerri, Eduardo, & Chone, 1990, p.1)"

- **Leachate** - "Leachate is liquid that extracts solutes from other matter as it passes through it. In an environmental sense, leachate most commonly refers to water acquiring properties from the refuse that it contacts (Scott Environmental Group, 2012)."

- **Vermicomposting** - "This type of composting involves the cultivation of heat-loving, or thermophilic, microorganisms in the composting process. Thermophilic microorganisms, such as bacteria and fungi, can create an environment in the compost which destroys disease organisms that can exist in human excrete, converting excrete into humus (Jenkins, 2005, p.26)."

## 1.9 Summary

The global water crisis is demonstrated with substantial proof and needs to be addressed in multiple forms. Through global efforts such as the Millennium Development Goal, clean drinking water has been provided to more people around the world. However, there is still a large population left without clean water that requires aid. In the future, more countries will be at risk of water shortages as climate change changes precipitation patterns and the demand for water increases with population. "Under the business-as-usual scenario assumed in this analysis, total water demand is projected to increase by as much as 12.3 percent between 2000 and 2050 (Natural Resource Defense Council, 2010)."

The use of composting toilets in use in public areas with high foot traffic would save a vast amount of water and benefit the surrounding environment. With thorough research and planning behind the choice of installing composting toilets in urban and suburban areas in lieu of conventional toilets, water would be conserved for others and less water would be used in the future in the likely case of unreliable water provision.

Society in many cultures plays a part in aiding those in need by increasing efficiency in water use. It has become a part of Western, developed culture to separate itself from its waste with the luxury of knowing others will dispose of it. Waste is kept out of site for reasons concerning health, way of life, and the social stigma of facing personally created waste. In order to mitigate the current and future issues with clean, available water for as much of the global population as possible, individuals of developed societies all over the world must accept more personal responsibility for the sustainable disposal of waste.

This study strives to understand the hesitance in the use of composting toilets. Specifically, the barriers to the adoption of composting toilets into urban and suburban use will be explored. By interviewing stakeholders in the field of composting toilets, an argument created from multiple points of view constructs a balanced understanding of the barriers of composting toilet adoption.

# CHAPTER 2. REVIEW OF RELEVANT LITERATURE

This chapter contains a review of all the documentations and research which the researcher used to as a knowledge source.

## 2.1 Barriers to Innovative Technology Adoption

The potential benefit of a technology to society does not guarantee an easy path to adoption by communities. The technology of composting toilets is no exception. Different theories deconstruct the different characteristics of technology adoption. "Adoption theory examines the individual and the choices an individual makes to accept or reject a particular innovation (Straub, 2009)."

The adoptable nature of each technology is unique. The specific qualities of each technology influence the decision makers in charge of choosing to adopt a new, improved technology or process. Innovation Diffusion Theory, (Rogers, 1995), investigates individual adoption as well as the diffusion of an innovative technology throughout society. It is suggested that his theory "has become the classic reference for discussion of innovative technology adoption and its diffusion through society (Payne, Radspieler, & Payne, 2002)." Roger's Theory explores the individual innovation, communication channels connecting the innovation to the consumer, the societal environment of the innovation, and the time frame of the adoption process.

Part of his theory discusses five variables that provide a uniform way to assess the perceptions of the innovations qualities to the decision makers. The perceived attributes are relative advantage, compatibility, complexity, trialability, and observability. These five variables provide a uniform way to assess the perceptions of the innovations qualities to the decision makers.

> "Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes... Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters ...Complexity is the degree to which an innovation is perceived as difficult to understand and use... Trialability is the degree to which an innovation may be experimented with on a limited basis... (and) observability is the degree to which the results of an innovation are visible to others (Rogers, 1995)."

Roger's theory is diverse, applicable in both formal and informal environments. This flexible nature has aided multiple areas of research such as consumer behavior, agriculture, societal implementation, and more (Straub, 2009).

The Theory Acceptance Model (TAM) uses two variables to comprehend the usage of the innovation; perceived ease of use and perceived usefulness (Davis, 1989). Davis brought attention to the individual perception of a technology as well as the perception differences individuals within a population (Straub, 2009). However, Davis (1989) has limited acknowledgement of the different facets of individual perception. His theory does not evaluate a technology with the consideration of demographics and the unique characteristics that differentiate people.

A similar theory though more complicated, the United Theory of Acceptance and Use of Technology, is relatively new and based on eight historical models of individual adoption. The UTAUT "includes four key determinants of use and four moderators of individual use behaviors (Straub, 2009)." The determinants describe an individual's beliefs and perceptions about the technology's ease of use, ability to assist in performing tasks, the pressure from society to use the technology, and the role played by the individual's organization in supporting the acceptance. The four moderators describe the individual's characteristics such as age, gender, experience, and voluntariness of use (Venkatesh, Morris, Davis, & Davis, 2003). Given the recent development of this theory, it requires more time and study to compare to the use of Rogers (1995) model or the TAM (Davis, 1989).

Each technology is different, and no theory of adoption can explain the rate of adoption for every innovation. These three theories are only a few examples available to analyze innovations and their acceptance.

## 2.2 A Brief History of Composting Toilets

For as long as humans have lived together and formed ways of working as collective group, there has been the need to dispose of waste to assure hygienic standards. In approximately 1700 B.C., the Minoan Palace of Knossos on the isle of Crete was one of the first cited civilizations to use a process of diverting waste to be used in fields with other household wastes (Bull, Betancourt, & Evershed, 2001). In some Asian cultures, human waste has been utilized for agriculture in the form of night soil; the raw application of night soil to fields. Though not recommended for modern use, night soil played a crucial role in agricultural development in different countries. Cities in China, South Korea and Japan use night soil to grow vegetables (Jenkins, 2005). The use of human and animal excrete in Chinas fields, both as night soil and as a product of composting methods, yielded in high agriculture output to meet the demands of a large, and hungry, population (King, 1911). The use of burial of human excreta for future compost was used during the 1960s in North Vietnam:

> "Thousands of vault privies were built as part of a widespread program of rural sanitation. The concrete tanks consisted of two watertight compartments with a top square plate. When one side is almost full, green leaves are added and the hole is sealed. After three months of decomposition, the material is removed for agricultural use. Meanwhile, the other side is used and the cycle begins again (Van der Ryn, 1978)."

There is a sharp contrast in comparing this to the image of Medieval Europe of citizens pouring the contents of their waste into the streets. However, in the 19th century, earth closets became commonly used to combat the spreading of disease through water borne treatment. An earth closet consists of a simple design; a bucket below a seat to collect waste (Van der Ryn, 1978). Before the arrival of central sewage into Western Europe, different forms of composting toilets had provided viable solutions to hygienic and spatial issues.

The Clivus Multrum was the first of the modern aerobic compost toilets and appeared in 1939 in Sweden (Stoner, 1977). Since the production of the Clivus, the look and make of composting toilets has changed little in principle. However, since the emergence of this design, composting toilets have been adapted to serve different population sizes in different locations. Composting toilets have developed with civilization through history and continue to play a role in todays societies.

## 2.3 What are Composting Toilets?

Composting toilets are a method of dry sanitation, defined as "on-site disposal of human urine and feces without the use of water as a carrier (Peasey, 2000)." Dry sanitation with composting toilets is generally accomplished with the goal of reusing the compost for agriculture or to enrich soil; a goal where nutrients can be reused safely. Dry sanitation with the intent of reuse is categorized in two ways:

> "Dehydration – Urine and feces are managed separately. The deposited fecal matter may be dried by the addition of lime, ash, or earth and the contents are simply isolated from human contact for a specified period of time to reduce the presence of pathogens. Decomposition (composting) – In this process, bacteria, worms, or other organisms are used to break organic matter down to produce compost. The temperature and airflow

are carefully controlled to optimize conditions for composting (Peasey, 2000)."

A composting toilet is defined throughout an abundance of research. The term composting toilet is sometimes interchanged with the terms bio-toilet. However, some researchers find these terms to mean different types of alternative toilet systems within the topic of sustainable waste management. The Environmental Protection Agency (EPA) uses the following definition: "A composting (or biological) toilet system contains and processes excrement, toilet paper, carbon additive, and sometimes, food waste. Unlike a septic system, a composting toilet system relies on unsaturated conditions where aerobic bacteria break down waste (United States Environmental Protection Agency (US EPA), 1999)." Research by Zavala, Funamizu, and Takakuwa (2005) slightly challenges this definition by classifying bio-toilets as being a type of composting toilet with a different composting process. They state that "unlike the conventional composting systems, the composting process in the bio-toilet is a continuous, thermophilic aerobic biodegration process, where human excreta is treated and it is managed with the aim of minimizing any potential environmental or nuisance problems (odour)." This research will use the definition provided by the US EPA.

## 2.4 The Chemistry of Compositing

Composting is a naturally occurring process in nature that can be found in two forms; aerobic and anaerobic. Aerobic decomposition can be viewed on the ground of a location of biodiversity like a garden or forest. "Dead leaves, animal remains, feces and other materials are stirred and broken up by the passage of animals and insects. Bacteria that live in the presence of oxygen process the material through a series of chemical changes which reduce its mass to about one-twentieth of its initial volume (Van der Ryn, 1978)." The product of aerobic decomposition is humus and carbon dioxide. This process also creates topsoil which is necessary for human agriculture, though its production is a very slow process.

Anaerobic decomposition occurs in locations where oxygen is lacking. "Anaerobic digestion is a biological process that happens naturally when bacteria breaks down organic matter in environments with little or no oxygen (Friends of the Earth International (FoEI), 2007)." This produces methane that is unpleasant in odor; therefore in general it is undesirable in the case of composting toilets or compost occurring near residences.

"Usually, the conventional composting process has been divided into four different phases: mesophilic, thermophilic, cooling and maturing, according to the temperature in the compost pile (Xiao et al., 2009)." During the mesophilic stage, mesophilic bacteria flourish and raise the temperature of the compost up to 44C. At this temperature, it is still possible for disease-causing bacteria from inside the human intestinal track to survive. In the transition to the thermophilic stage, harmful pathogens are unable to survive due to living outside of the human intestinal track and the high temperature for extended periods of time. The higher temperature material tends to be centralized in the upper part of the compost pile where new material is continuously added. In batch composting, the entire mass may be thermophilic at once. This high temperature phase can last between a matter of days or months. The cooling phase, microorganisms that were deterred by heat return to the compost in order to digest resistant organic materials. Fungi and macroorganisms transform the granular portions of the compost into humus. The final stage, the maturing (or curing), is a waiting game that ensures a hygienic compost that can be reused has been produced. A year-long curing period is a suggest time period to subject any residual pathogens to a competitive environment that decreases chances of pathogen survival (Xiao et al., 2009).

The finished product of composting shows a reduction in volume and a change in color of the materials. The maturity of compost is important to understand the proper timing of use. "Compost that is not mature can be phytotoxic and polluting. Mature compost is a biochemically beneficial as a supplier of plant nutrients...(Agnew & Leonard, 2003)." Adding compost to soil as a conditioner has shown results of "decreased bulk density and strength, increased porosity and enhanced water retention and available water of plants (Agnew & Leonard, 2003)." This has made compost a popular pass time of many consumers for use in gardens and farmland. The opportunity proposed by composting toilets is an abundance of composting material that may be sold or used by nearby rural or park locations as a soil enricher.

### 2.4.1 Optimizing the Composting Process

Specifically for composting human excrete; aerobic, thermophilic composting is a highly suggested form of composting. Four variables are highlighted to be monitored for an optimum composting process: aeration, moisture content, carbon/nitrogen ratio, and the size and temperature of the pile (Jenkins, 2005; Van der Ryn, 1978).

Aeration is needed because create a viable environment for aerobic bacteria. Proper aeration starts with adding a loose layer of carbonaceous and dry material at the bottom of the compost pile and by turning the compost pile frequently. By turning the material in a compost pile, the rate of decomposition increases and the temperature of the pile are raised. Vents to intake air can be constructed within the compost pile to distribute air evenly to ensure balanced oxygen content (Van der Ryn, 1978).

Moisture content of a compost pile is important because moisture us both produced and required for microbial action in compost. The metabolic process of microbes is supported by the moisture in a compost pile (Hall, Aneshansley, & Walker, 1995). "Fecal matter is 65-80 percent moisture and six to eight percent nitrogen, so they must be balanced with three or four parts of a fine dry material (Van der Ryn, 1978)." The climate of a location is important as it exposes the compost pile to different levels of moisture. Moisture to a pile can come in the form of rainfall, urine, food scraps, or graywater. Residential water may also be used, but sustainable options are always best to consider.

The diet for a compost pile is comprised of materials containing carbon and nitrogen. The ratio of carbon to nitrogen is important to aid in the microbes decomposing the pile. Feces contain about six percent nitrogen while urine contains 15-18 percent nitrogen. Aerobic decomposition is ideal within a range of 20 or 30 parts carbon to one part nitrogen (Jenkins, 2005; Van der Ryn, 1978). Carbon provides energy while nitrogen provides protein, genetic material and cell structure. When too much nitrogen is available, the excess nitrogen is converted into ammonia gas. Human excrete, urine, food refuse, garden weeds, grass, straw, hay and sawdust are all suggested options to balance a compost pile. An easy system to remember what contains nitrogen and what contains carbon used by backyard composters is categorizing material into "browns" and "greens". "Browns", dried leaves and sticks, supply carbon while the "greens", such as grass clippings, provide nitrogen (Jenkins, 2005).

Finally, the size and temperature of a compost pile must be monitored. A compost pile should be roughly a cubic yard to assure proper insulation. If a pile is too small, temperatures may not rise to an ideal 71 degrees Celsius in the center of the pile. When a compost pile is too hot, dehydration can occur which stops the decomposition process as will freezing. However, materials can be added on top of a frozen compost pile, and the composting process can continue once the pile thaws (Jenkins, 2005; Van der Ryn, 1978).

Three types of bacteria are seen in composting; psychrophiles, mesophiles and thermophiles. The types of bacteria witnessed in a composting toilet also help in their classifications of composting toilet type and efficiency (Chapman, 1994; Jenkins, 2005). Knowing these types of bacteria help a reader to gain a thorough understanding of composting toilets. Psycrophiles live in low temperatures that ideally grow in temperatures of 15°C or lower, though they have been seen in temperatures as low as $-10°C$. Mesophiles are medium temperature bacteria that live in $20 - 45°C$. In this temperature range, human pathogens can thrive. Thermophiles live in high temperatures above $45°C$. This high temperature bacteria are ideal to occur in the composting process of composting toilets due to their ability to decompose material quickly while disease-causing pathogens are killed (Jenkins, 2005).

## 2.5 Types of Composting Toilets

Composting toilet types can be grouped in different ways. They may be grouped according to the temperature of compost product (low-temperature or thermophilic) or the style in which the compost is handled (batch, continuous, self-contained, remote, or vermicomposting). Each kind of composting style or toilet will be explained in the following section.

### 2.5.1 Low-Temperature

Low-temperature compost is refuse that has not reached pathogen-killing temperatures (Jenkins, 2005). With this method, dehydration plays a key role of bring the compost pile to its final form. Low-temperature composting is used in cases where constant addition to a compost pile is not available and regular maintenance of a composting toilet is not an option or desire such as most commercial and homemade composting toilets. Another name for this type of toilet is a mouldering toilet. "Typically, they operate at room temperature and compost a mixture of feces and bulking material such as sawdust. Some accept urine as well, though many do not. Over the course of several months they convert the humanure/bulking material mixture into a mostly-composted, odorless product that is periodically removed (Noè-Hays, 2000)." This type of composting does not bring the composting pile up to a proper pathogen-killing temperature. Due to this, it is not suggest that the compost created from this method be used on food crops or in food gardens. Instead, the compost may be used as a soil conditioner away from food crops or may be safely used in a flower garden (Van der Ryn, 1978).

The only maintenance required for a low-temperature composting toilets is to rake the collected pile a few months apart. This can be done through access doors with rakes that stretch into the room that do not require the caretaker to physically be within the compost pile. In general, two chambers are used. One chamber sits for a year or two at a time to assure proper compost and sanitary conditions are met while the other chamber is used by the residence. Keeping in mind proper balance of organic compounds, carbonaceous organic matter is added after each use to prevent a negative odor (Jenkins, 2005).

For all practical purposes, pathogens in the manure will be gone in four months, and certainly in a year, but just to be perfectly safe, two years of aging will make sure (Logsdon, 2010). Similarly, Feachem, Bradley, and Garelick (1980) stated that a minimum retention time of three months produces pathogen-free compost with the exception of some intestinal worm eggs. In some cases, the compost can then be removed to an outdoor compost bin, covered with straw or other organic materials, moistened, and left for an additional 1-2 years to assure no pathogens are left (Feachem et al., 1980). A more detailed section on pathogen destruction through composting will follow in the literature review.

### 2.5.2 Thermophilic

Thermophilic compost is brought up to a high enough temperature to kill disease-causing pathogens. “Thermophilic Composting is breaking down biological waste with thermophilic (heat loving) bacteria (Wadkar, Modak, & Chavan, 2013).” Thermophilic composting relies on the natural heat of waste decomposing in a carefully maintained location. “During aerobic composting aerobic micro-organisms oxidize organic compounds to Carbon Dioxide, Nitrite and Nitrate. Carbon from organic compounds is used as a source of energy while nitrogen is recycled (Sundberg et al., 2011)." During this reaction, the temperature of the mass rises.

The hardest part to achieve thermophilic conditions is the requirement of regular collection and addition of organic material to maintain the composting process. The user must keep a watchful eye on the chambers or pile to assure enough human and plant material are balanced and raked to be flattened regularly via raking or puncturing. This can increases required maintenance of the toilet system. Large amounts of materials are required to insulate and keep a compost pile thermophilic.

To provide an image of a thermophilic composting process, a simple family farm setting will be used. The constant contribution of material from humans and animals provides a large amount of material to insulate thermophilic composting. After each use into the initial receptacle, a layer of clean, organic material must be poured on top of the building pile. Examples of these organic materials are rotted sawdust, peat moss, leaf mould, hay, or grass clippings. When a certain amount of excrete, including urine, it is deposited to a location outside built to hold an expanding pile of compost. With each addition to the pile, a small imprint is made in the top of the pile to deposit the new materials. This is done to keep the hot, thermophilic action in the center of the pile. After each addition in the main compost pile, new organic material must be added on top. This avoids smell and aids in the composting process. Raking of the top of the pile is done regularly to give air access to the pile, discouraging anaerobic conditions. Once one pile is large enough and has been heated, it must be left to age and complete its composting process to a safe material. At this stage, macroorganisms and fungi take over to decompose the material. During this stage, a second designated location is used to build a new pile (Jenkins, 2005).

Figure 2.1. The Humanure Hacienda (Joseph Jenkins Inc., 2013).

### 2.5.3 Batch

Batch compost is created by collecting all materials at once to sit in a receptacle until the compost process is finished. When one receptacle is finished, another is substituted for use as composting finishes in the previous receptacles. EcoTech, a composting toilet production company, explains the specifics behind a batch composting toilet: "By not continually adding fresh excrement and urine to older, more advanced material, the material decomposes more thoroughly, uninterrupted by the added nutrients, pathogens, salts, and ammonia in fresh excrement. Also by dividing the material, it can have more surface area, and thus better aeration. (EcoTech, 2013)."

The batch composting process takes less effort to bring to pathogen-killing temperature when properly managed. “Masses of organic material newly assembled for batch-type composting can self-heat from mesophilic to thermophilic temperatures within a few days (Suler & Finstein, 1977).” Batch composting can occur on a residential or a large-scale basis. An example of a batch composting toilet is the EcoTech Carousel. The EcoTech carousel composting toilet system has four rotatable compost chambers.

> “The compost container consists of an outer and an inner rotatable container. Excrement, paper, and organic kitchen wastes are disposed of into one chamber at a time. Liquid drains into the bottom of the outer container, where warmed air drawn into the container evaporates it. The resulting vacuum assures that no odor escapes into the room. When one chamber is full, the next one is turned into position, assuring that fresh waste does not disrupt the more advanced composting material (EcoTech, 2013).”

Unlike an outdoor compost pile that must be raked, batch composting only requires monitoring how full the compost container is and how soon a new container is needed.

### 2.5.4 Continuous

A continuous composter uses a single chamber into which excrement is added to the top, and the end-product is removed from the bottom of the chamber. This simple process is found in commercial composting toilets such as the Clivus Multrum, Phoenix, BioLet, and Sun-Mar (Del Porto & Steinfeld, 1972). The Clivus Multrum is one of the most widely known and successful brands of commercial composting toilets. This continuous compost toilet design is simple and effective, which has resulted in its use in business and residences around the world. The Clivus system uses a composting process in one large chamber in contrast to a batch system that uses multiple chambers that causes the composting process to begin again after emptying. “As the organic material decomposes it will reduce in volume by up to 90%. The compost pile is therefore always shrinking in the middle whilst new material is being added to the top, and finished compost is removed from the bottom of the pile when appropriate (Clivus Multrum Australia, 2013).”

As explained earlier, moisture content is crucial to a healthy compost product. A continuous composting toilet can be kept moist more easily than a batch composting process because of continuous intake of liquid. Temperatures may also remain more constant. “Proponents of continuous composting maintain that it is simple (takes place in one fixed reactor), allows urine to constantly moisten the process, and allows the center of the mass to heat up through uninterrupted microbial activity (Del Porto & Steinfeld, 1972).”

### 2.5.5 Self-Contained

A self-contained composting toilet is simply a toilet seat directly above the basin that collects the human refuse for composting. “The toilet seat and a small composting reactor are one unit which is most commonly found in small cottages and villages.”A centralized or remote composting toilet is connected to a composting reactor that is somewhere else. This is seen in small residential spaces that do not have room for the composting receptacle in the same location as the toilet (Del Porto & Steinfeld, 1972).

### 2.5.6 Vermicomposting

Vermicomposting is an intricate composting technique based on a high level of biodiversity within the composting tank. Worms are used in the compost to deposited waste into a soil conditioner with properties similar to gardening soil. “Worms such as the common nightcrawler (Lumbricus terrestris) encourage the decrease of Salmonella typhimurium bacteria, which produce intestinal disease in humans and some animals, and increase the density of beneficial bacteria that aid in the breakdown of organic matter (Raloff, 1980)." Red worms (Eisenis fetida or Lumbricus rubellus) can be used with compost kept in a dark, cool, well-aerated space with adequate moisture content (Jenkins, 2005). "Compared to conventional microbial composting, vermicomposting produces a product that is more or less homogenous, with desirable aesthetics, with reduced levels of contaminants and tends to hold more nutrients over a longer period, without impacting the environment (Ndegwa, Thompson, & Das, 2000)."

The worms moving through and digesting waste and excrete aerate the compost pile. When feeding on the pile contents, the surface area of the compost material is increased giving it more exposure to air. As a result, aerobic organisms have a better environment to thrive in (Raloff, 1980). "Vermicomposting is also a bio-oxidative process which engages earthworms and microorganisms. The microorganisms, both in the earthworm guts and in the feedstock, are responsible for the biochemical degradation of the organic matter whilst the earthworms are responsible for the fragmentation of the substrate, which increases the surface area exposed to the microorganisms (Fornes, Mendoza-Hernàndez, Garcìa-de-la-Fuente, Abad, & Belda, 2012)."

Though the temperature of the pile increases from worms encouraging aeration, this process is different from thermophilic composting. High temperatures within a pile drive away or kill the worms in a compost pile. Vermicomposting requires a narrow range in temperature in order to provide a healthy environment for the worms. Ideally, the worms live in a range between 25°C and 40°C, followed by a neutral pH and a high humidity (7090%) to sustain a large population of worms (Fornes et al., 2012). Due to the lower temperatures of vermicomposting, pathogen-killing temperatures are not reached. The chances of harmful pathogens are higher in the product of vermicomposting, but the nutrient content is higher in the final product, which awards it a higher value in benefiting soil. The use of vermicomposting meets objections due to its requirement of lower temperatures. A method combination of composting and vermicomposting has been a proposed solution. "The proposal for a combined system is based on the premise that composting enables sanitization and elimination of toxic compounds and the subsequent or preceded vermicomposting rapidly reduces particle size and increases nutrient availability (Fornes et al., 2012)."

## 2.6 Pathogens and Viruses in Human Waste

The risk of spreading harmful pathogens through using human excrete is one of the main deterrents in the subject of composting toilets. Human fecal matter can transfer viruses, bacteria and parasitic worms, which is an obvious cautionary variable in the decision to use composting toilets. "When discussing human excrement systems, the diseases we are concerned about include amebiasis, cholera, cryptosporidiosis, gastroenteritis, infectious hepatitis, parasite-related disease, salmonelliosis, shigellosis, typhoid fever, and other diarrheal disease (Del Porto & Steinfeld, 1972)." The risks to using composting toilets have been well researched and are combatted with different solutions. Many factors determine the true risk of using a composting toilet: the health status of the population who may use the toilets, the maintenance and construction of a composting toilet, and what the compost from the toilet is used for.

### 2.6.1 The Transfer of Pathogens

The transfer of pathogens from composting toilets can occur through contact with direct contact with infected material or vectors. Handling fecal matter for composting can cause transfer of pathogens if sanitary measures are not met. The concept is simple, but washing hands and all areas that come into contact with the compost is the most important prevention technique in preventing the spread of disease. "Hand washing breaks the primary connection between surfaces contaminated with fecal organisms and the introduction of these pathogens into the human body. The use of basic soap and water, not exotic disinfectants, when practiced before eating and after defecating, may save more lives than all modern methodologies and technologies combined (Del Porto & Steinfeld, 1972)."

"In the field of environmental health, a vector is any organism that conveys disease to another organism. Vectors are an important consideration in the design and installation of composting toilets, because they can be a carrier of excrement (Del Porto & Steinfeld, 1972)." Common vectors are flies, rats, dogs, beetles, mites and arthropods. Vectors with the ability to contact human excrete and then come into contact with food or water to be ingested pose a great threat in spreading disease. The best way to keep vectors out of the compost pile to stop harmful transfer is by denying access via secure containment of the excrete. Some suggested methods to stop vector access are: "screen ventilation openings, seal cracks and openings (a smoke test can reveal them), or to apply environmentally benign insect repellents such as pyrethrins and diatomaceous (Del Porto & Steinfeld, 1972)." Keeping a careful eye on the composting process and assuring no access to undesired creatures is the most effective way of avoid pathogen transfer via vectors.

### 2.6.2 Health of Population

Pathogens are found in human excrete when the host is already subject to a bacteria, virus, etc. If a human does not have any pathogenic organisms in their intestines, their fecal matter will not be of risk of passing on disease. "In the U.S., the incidence of fecal borne diseases is extremely low. Few people carry the pathogenic organisms in their intestines and they are not, therefore, present in the feces. Traditionally, these diseases are caused by the immediate pollution of drinking water by fecal matter, or by the use of infectious raw sewages as fertilizer on edible plants (Van der Ryn, 1978)." A person may not show symptoms of harmful bacteria but still be a carrier. Composting toilets in the location of a generally healthy population largely decreases the risk of spreading disease, though following every precautionary step is still necessary. In contrast, composting toilets installed in a population with higher climate temperatures and poor population health increases risk of pathogen transfer through human feces. Despite the increased risks of transferring disease through composting human feces in populations with higher health concerns, “dry toilet systems are widely promoted as a suitable entry point to fulfill the sanitation target set in developing countries (Germer, Yongha, Schoeffler, & Amoah, 2010).”

The risk of pathogen transfer is also determined by the climate of use. “In northern climates where the temperature drops below freezing, Ascaris lumbricoides (roundworm) is virtually nonexistent. However, in warm climates it is a common pathogen excreted by humans, dogs, cats and other animals. The risk, therefore, is lower in the North than in the South (Del Porto & Steinfeld, 1972).”

### 2.6.3 Maintenance of Compost

When not maintained properly, a composting toilet may transfer pathogens through the fault of the installer or caretaker. Like many sustainable technologies, the benefits of a composting toilet may not be reached when it is not constructed or maintained properly. To combine multiple factors of human health, vectors and maintenance, Jenkins states that in the case of composting toilets, “there is no reason to believe that the manure of a healthy person is dangerous unless left to accumulate, pollute water with intestinal bacteria, or breed flies and/or rats, all of which are the results of negligence or bad customary habits (Jenkins, 2005).” Immature, unhygienic compost and vectors are common results of poorly cared for composting toilets. If the carbon/nitrogen balance is not respected, the pile is not turned enough or too much, too much or too little moisture is observed, or the temperature of the pile is not adequate, the human fecal matter will not compost properly and put others at risk if taken out of the composter. If the pile matter is left unattended and uncared for, vectors have more time to find access and breed within the composter.

### 2.6.4 Purpose of Compost

Compost can be used as a soil conditioner or as fertilizer. When used as fertilizer for food crops, transfer of pathogens becomes possible, though not likely if the compost has been composted and matured properly. Though many cultures use the fecal matter of livestock and humans to produce compost for agricultural use, the most effective way to have more composting toilets installed in other countries is to assure that the compost created from composting toilets is used as a soil conditioner or for gardens containing non-food crops.

Currently, the process in which humans consume food leaves a gap in a cycle of nutrients. Humans use crops for food and gain nutrition from their consumption. Once digested, the nutrition leaves the body in the form of urine and fecal matter. With conventional toilets, the human excrete is flushed away and unable to be used or to return nutrients to the environment.

Closing the gap of human consumption and giving nutrients back to the environment is the idea behind ecological sanitation. Humans consume food grown from crops, and the fecal matter contains nutrients that can be used by plants and microbes to benefit soil and the surrounding environment when disposed of with ecological sanitation in mind.

The sanitary compost end-product could be used as fertilizer for crops, gardens or as soil conditioner. However, the only way to be entirely sure that no harmful pathogen would ever be passed due to the use of human excrete compost would be to only use such compost for gardens with non-food crops or soil conditioner. Certain researchers and publishers in the field of composting toilets would strongly disagree and suggest compost from human fecal matter is an essential stop in feeding the world population (Dellström Rosenquist, 2005;

Jenkins, 2005). This research approaches this topic from the primary standpoint of sanitation and installation of composting toilets in urban and suburban locations. Urban spaces are home to denser, larger populations, increasing the chance of harmful pathogens passing into the excreta to be composted.

## 2.7 The Social Stigma of Composting Toilets

The topic of composting toilets is worthy of intensive research because human waste has been and always will be a constant variable in developing areas for human occupation. In the past, "poor management of waste led to contamination of water, soil and atmosphere and to a major impact on public health... Well-publicized industrial accidents, often unrelated to waste management activities, have produced a NIMBY (not in my backyard) syndrome that causes fierce opposition to the construction of landfills, incinerators, or other waste disposal facilities (Giusti, 2009)." Though systems have advanced, leaving cities and human developments separated from waste and more hygienic, a block has been formed in peoples perceptions of human waste being in close vicinity to living space. Instead of viewing human excrete as a resource; it is viewed as a burden that should be removed for someone else to dispose of. The design of standard sanitation technologies in developed countries is based on the premise that excreta are waste and that waste is only suitable for disposal (Esrey, Anderson, Hillers, & Sawyer, 2001). A new view in society is needed that views all organic waste created as a resource to be recycled and cared for properly. As Van der Ryn (1978) notes, "Our excreta–not wastes, but misplaced resources–end up destroying food chains, food supply and water quality in rivers and oceans... How did it come to pass that we devised such an enormously wasteful and expensive system to solve a simple problem?"

### 2.7.1 Historical Attitude Towards Human Excreta

This mental block of using human excretes as a resource is largely a result of historical influence. Through history, the ability to separate oneself from waste and excrete has been a symbol of social status and economic welfare. The further from living in personal filth one could be indicated a healthier and more successful life. A proper way of disposing of excrete was a sign of a developing culture. “For centuries, class distinctions separated the odor, dirt and smell of the Unwashed Masses from those privileged to escape the ritual of emptying slops into the streetin America, the census celebrated the spreading of democracy by noting the growing number of flush toilets (Van der Ryn, 1978).” Western societies have adopted a waterborne waste disposal technology that it is now an expectation of the culture.

### 2.7.2 Desire to be Removed from Excreta

The desire to be separated from excrement stems from more than history alone. Many societies prefer the conventional method of waste treatment to make excreting waste a minimal process that brings little attention to the process. “An overarching characteristic of sanitation is that we prefer not to talk about it, and that it is a subject surrounded by numerous unwritten rules and taboos. Humans want to be able to distance themselves; both mentally and physically, from perceived trouble and nuisance associated with excrement (Dellström Rosenquist, 2005).” Since composting toilets require frequent maintenance of ones own feces, the act of ecologically disposing of ones own feces will be a difficult barrier to overcome.

### 2.7.3 Psychological and Social Factors

Literature on composting toilets has explored the social factors between composting toilets and use in society, but more is needed to understand how to implement composting toilets more commonly. “What is surprising: the subject is not directly approached in the social sciences, e.g. cultural anthropology, human geography and behavioral psychology. This is unusual when one considers that the success of a treatment system depends on all the system components working together: device, process, nature, and society (Warner, 2004)."

A central issue in society adopting composting toilets is the attitude people have towards their own waste. "Technically speaking, attitude includes three elements of behavior: cognition, perception and a tendency to act (Warner, 2004)." To measure the attitudes of certain groups of people towards human excrete, the Body Elimination Attitude Scale was developed. Groups that are measured include occupations. "Although the scale does not predict behavior towards a particular toilet system, it does reveal that groups of people vary in their tolerance towards human excrement (Templer et al., 1986)." A strong connection was found between the occupation held by someone and their attitudes towards human excrete. Those with exposure to excrement such as nurses and sewage workers had a more accepting tolerance than further removed occupations such as food service personnel and bankers.

### 2.7.4 Cultural Factors

Cultures around the world have different levels of acceptance regarding the handling of human waste. "Although some cultures do not mind handling human excreta (faecophilic cultures), and others find it abhorrent (faecophobic cultures), most cultures are somewhere in between these two extremes (Warner, 2004)." Attitudes can change for the better when exposed to an alternative waste disposal system. Experts in ecological sanitation have found apprehension towards handling human excrement to disappear when people witness first-hand a well-managed toilet system (Winblad, 1998). "A second cultural issue is whether waterless toilets will be accepted in cultures where washing after defecation is mandated by tradition and religion (Warner, 2004)."

### 2.7.5 Religious Factors

Religion is a concern regarding composting toilets and use in large societies in regards to handling human excrement.

> “Moslem doctrine prescribes strict procedures to limit contact with fecal material. Only the left hand can be used for cleansing after elimination; the right is used for eating. Moreover, the use of water for cleansing is specified. That is, a Muslim is obligated to use water to cleanse parts of the body through which impurities pass (Hooi & Hamzak, 1995). This obligation has direct implications for planning toilet facilities. For example, the Malaysian Cabinet has directed local authorities to incorporate the water requirements of Muslims in the design of public toilets. Although Hooi and Hamzak (1995) state that these additional requirements have not presented problems to non-Muslim users, one cannot assume all theocratic directives are benign. It is understandable why Muslims would be hesitant to use a waterless toilet and why government directives might prohibit them (Hooi & Hamzak, 1995; Warner, 2004)”

A study by (Nawab, Nyborg, Esser, & Jenssen, 2006) of households in the North West Frontier in Pakistan found a strong opposition to ecological sanitation methods when compared to conventional toilet methods. They saw non-waterborne forms of toilets as “age-old fashion, backwards and a matter of taboo, while flush toilets are considered prestigious and desirable.” However, some Muslim communities utilize dry sanitation toilets. “In Yemen and Zanzibar, where waterless systems have been traditional, the users wash themselves away from the toilet opening. Since this has not posed a problem for traditional waterless systems, it might be an acceptable solution in other washing cultures. In fact, an example from India shows a dry toilet system was successfully introduced to a washing, Hindu culture (Warner, 2004; Winblad, 1998).” This research does not intend to analyze each religion and its attitude towards dry sanitation and composting toilets, but rather to show that religion must be taken into consideration as a possible barrier depending on where the toilet system is attempting to be installed.

### 2.7.6 Experiences with Human Excreta

Today, the opinions of western societies on alternative waste disposal technologies are still difficult to change. Reluctance to switch to a toilet system that is not waterborne may come from a lack of education, poor past experience, no past experience, desire for the cheapest short-term option, and many more factors. Consumers may be wary of a new, unfamiliar technology and the service providers of waste disposal may lack the motivation to install composting toilets due to upfront costs or the maintenance required. "Although there is a universal consensus that body wastes are sordid, our elimination behavior and our feelings about it are all learned from our experiences, and evolve and change over time (Kira, 1995; Warner, 2004)." The experience a person has with excreta forms their perception of the disposal method. Past experiences and knowledge of sustainable options largely determines the willing nature of someone to adopt a dry sanitation system.

## 2.8 Advantages of Composting Toilets

Composting toilets offer many advantages for all societies willing to adopt a new, sustainable technology that reincorporates personal excrement into daily life in a hands-on manner.

### 2.8.1 Water Use

An obvious advantage of using composting toilets is a severe decrease in water usage. Though alternative toilets that use graywater or low flow technology also reduce water use, composting toilets use little to no water, which is ideal.

"Composting toilets neither require water nor generate wastewater and, consequently, are an alternative, decentralized approach to management of human excreta. These alternative technologies can have good technical performance (Fewkes, 1999; Gajurel, Li, & Otterpohl, 2003; Ghisi, 2006) and if they have comparatively lower costs and environmental impacts they could replace the current potable water based sanitation systems in the future (Anand & Apul, 2011)."

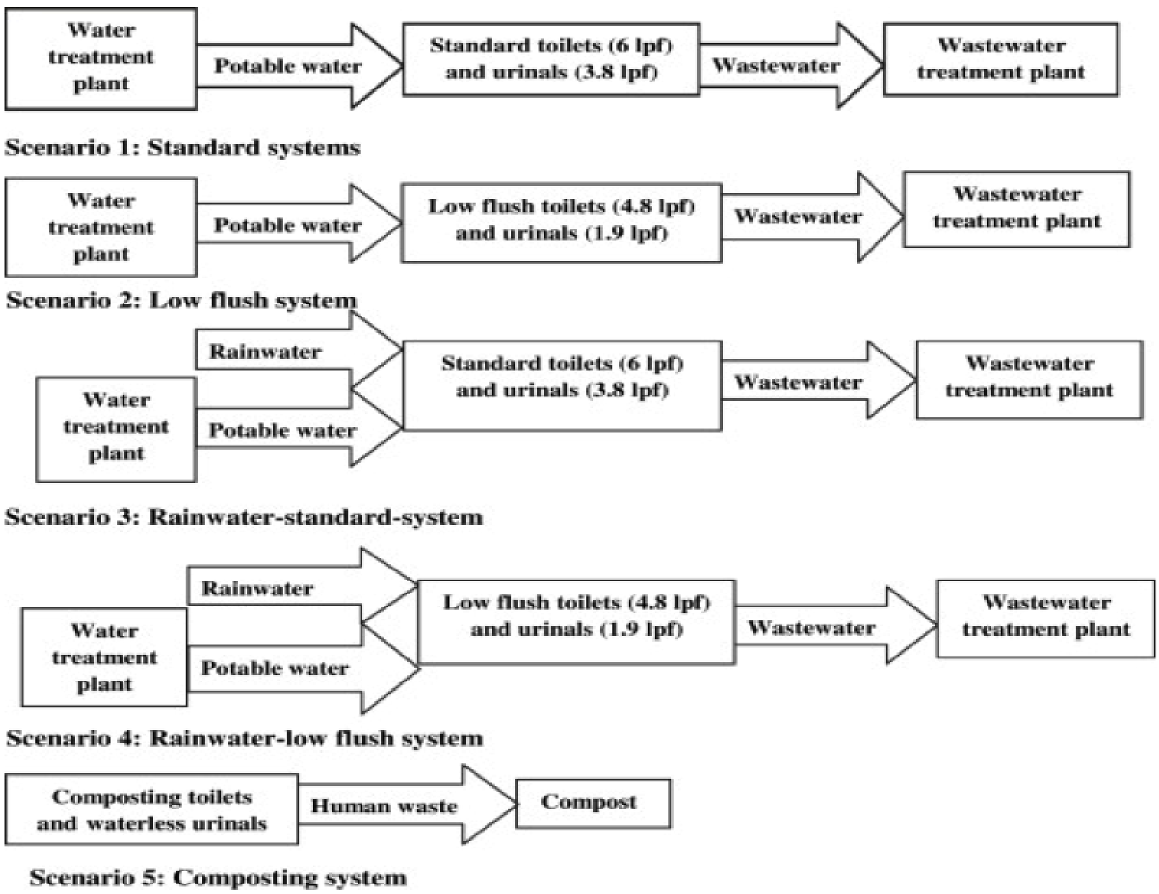


Figure 2.2. Water Flow and Amount Used by Other Systems (Anand & Apul, 2011).

A study by Anand and Apul (2011) compared five toilet systems; conventional, low flush, rainwater-standard, rainwater-low and composting toilets. An all-around economic and environmental analysis was conducted to understand which sustainable toilet systems were viable future solutions in theory and in practice. They concluded that, "while potable water would still be required for hand washing, the composting toilets themselves do not require any water for flushing and are, disconnected from the municipal water and sewer systems." Below is the graphical representation of water required to maintain a composting toilet in comparison to conventional and alternative systems.

### 2.8.2 Closing the Gap in the Nutrient Cycle

Composting toilets offer a solution to the current practice of wasting nutrients excreted by humans. Not only are composting toilets better for the environment by using less water and requiring less industrial construction, they recover and recycle nutrients. As mentioned earlier in the literature, composting toilets closed the gap in the cycle of nutrients. "Ecological sanitation is not merely about a new latrine design. It is a new way of thinking: a closed-loop-approach to sanitation, in which excreta are returned to the soil instead of water. Thus, the closed-loop approach is non-polluting, keeping fresh and marine water bodies free of pathogens and nutrients. It is a zero-discharge approach (Esrey, 2001)." Composting toilets may be used for agricultural purposes to improve crop output, but policies and preferences may not allow this practice. Used as a soil conditioner or to improve a non-food crop garden, humus from a composting toilet still closes the gap in the nutrient cycle.

### 2.8.3 Long-Term Financial Gain

The financial advantage of using composting toilets is long-term. The cost of an average, conventional toilet is generally in the range of $100 to $300. However, the total cost of a septic system installment is between $3,000 and $10,000, requiring extra fee when the septic system needs to be emptied (University of Minnesota, 2010). Maintenance and replacement of a septic system is a great financial burden. “On average, it costs homeowners $250 to pump their septic system, while the average cost of replacing a conventional septic system is $5,000 - $10,000. As the holidays approach, consider having your tank inspected and pumped (United States Environmental Protection Agency (US EPA), 1994).”

Composting toilets are costly purchases that must be taken care of to insure the goals of ecological and financial gain are accomplished. The Clivus Multrum, Envirolet and Sun-Mar systems will be used to understand the prices of the most commonly purchased composting systems. A Clivus Multrum waterless composting toilet system can cost from $3700 to over $8000 for larger house units and commercial units (Clivus Multrum Australia, 2013). Installation, maintenance and assistance are offered globally though satellite locations of the business. The Envirolet composting toilets range between $2200 and just over $6000. Like most commercially assembled toilets, a fan is installed with these systems to assist in air movement and to dry out the compost, which requires an electrical fan. If desired to keep electrical costs as efficient as possible, a solar kit is offered with Envirolet toilets that costs $800. This solar kit works for a single toilet. For homes and cottages, solar kits cost $5,000 to $25,000 depending on size of the cottage and the amount it is used (Envirolet, 2013). Sun-Mar features compact and central toilets costing around $1,500 to $2,000. They also feature garden composters for $200-$500 (Sun-Mar, 2013).

Initial installation of the composting toilet is important to factor into the total cost of a composting toilet system. National Small Flows Clearinghouse published a fact sheet outlining the basics of composting toilets; basic definitions, graphic representation, advantages, disadvantages, etc. Included in this document is an approximation of composting toilets for family homes and public facilities:

> “For a year-round home of two adults and two children, the cost for a composting toilet system could range anywhere between $1,200 and $6,000, depending on the system. Cottage systems designed for seasonal use range from $700 to $1,500. Large-capacity systems for public facility

use can cost as much as $20,000 and more. However, site-built systems, such as cinder-block double-vault systems, are as expensive as their materials and construction labor costs. A septic tank and soil absorption or subsurface irrigation system to manage graywater will usually be required (C. Solomon, Casey, Macknee, & Lake, 1998)."

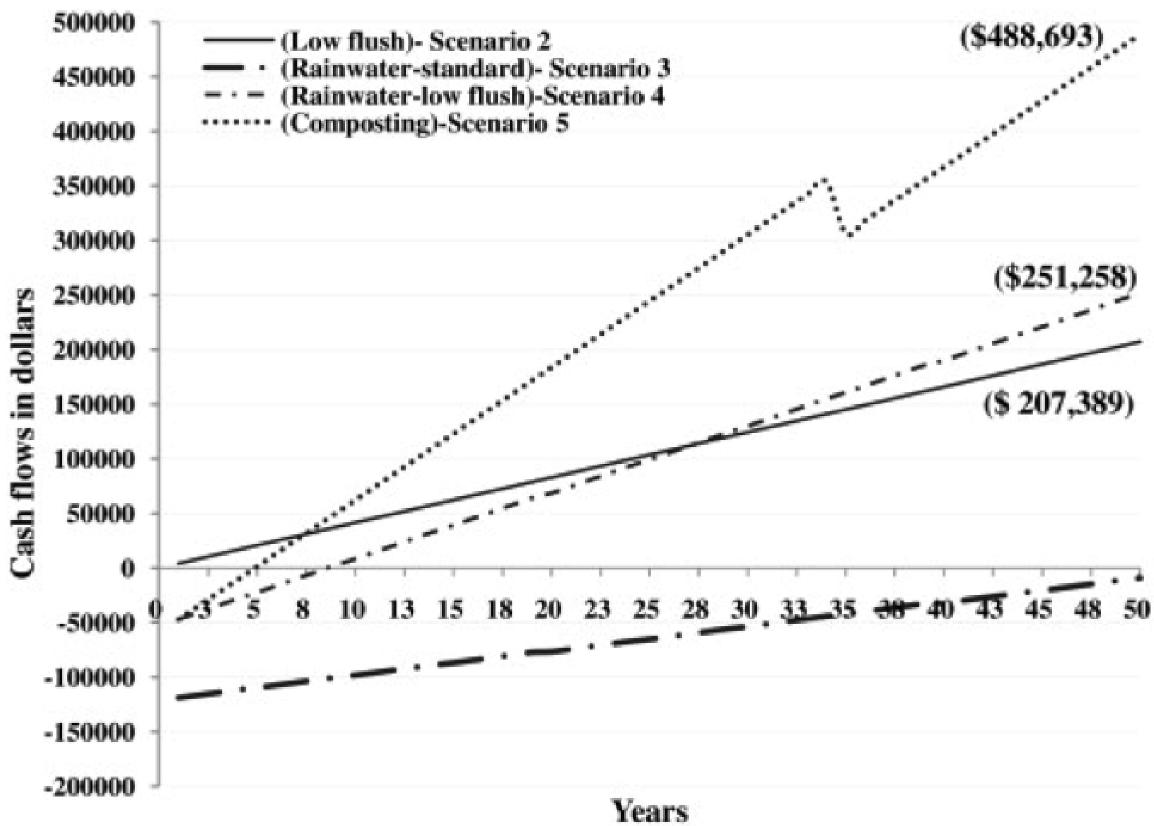


Figure 2.3. Cash Flow Representation of Conventional and Sustainable Toilet Systems (Anand & Apul, 2011).

Composting toilets are an initial financial burden. However, with proper maintenance, a composting toilet results in a long-term financial benefit. Figure 2.3 represents a graph created by Anand and Apul (2011) after five different types of toilets were compared. Composting toilets in theory and in practice have cut long-term costs that result in saving money over the life of the toilet.

### 2.8.4 Improved Sanitation

Composting toilets are proposed for developing countries due to their ability to improve sanitation in residential spaces and the capability to improve the quality of drinking water. When composting toilets are used instead of conventional toilets, water is used for efficiently and in locations where it is needed most. “Drinking water is preserved for drinking, rather than flushing. The environmental and human health risks are minimized or eliminated. Fish populations, coral reefs, and biodiversity are protected. Nitrogen pollution, with adverse human health effects, is reduced (Esrey, 2001).” Using dry sanitation in urban, remote and developing locations has shown increased sanitation and better quality of life.

### 2.8.5 Improved Soil Condition

The loss of topsoil is a global experience that could be relieved, even if by a mere fraction, by the product of composting toilets. “The two main causes of degradation are loss of topsoil from water erosion and fertility decline. In Africa alone, 8 million tons of nutrients are lost every year, representing US$ 1.5 billion per year (Esrey, 2001; Henao & Baanante, n.d.).” Compost produced from homemade or commercial composting toilets aid the surrounding biodiversity by returning enriching nutrients. “When excreta are processed and returned to soil as organic matter, soil structure and waterholding capacity is improved and fertility is restored. Valuable nutrients contained in excreta, mostly in urine, are returned to the soil for healthy plant growth (Esrey, 2001).” The loss of topsoil is a threat to crop production and feeding increasing populations. This factor is monitored through many methods and analyzed in different ways. The retention of phosphorous and nutrients in soil is noted in research performed by Raudsepp-Hearne, Peterson, and Bennett (2010) regarding ecosystems and the tradeoffs resulting in desirable and undesirable ecosystem characteristics. In this publication, ecosystems with better soil quality and nutrient retention were linked to locations with better water quality.

This resulted in having more to offer in the future as far as resources and a healthy environment for tourism and commerce. "Soil organic matter and soil phosphorus retention were also positively correlated with a high number of other ecosystem services (ve and four positive correlations, respectively). Notably, soil phosphorus retention had a strong signicant positive correlation with drinking water quality... (Raudsepp-Hearne et al., 2010)." Returning nutrients to soil is a financial benefit to the agriculture industry. Healthier soil reduces the need for expensive fertilizer and other actions to increase crop yield. Better soil quality that leads to better water quality. "The loss of soil-regulating services is costly to farmers that have to replace these services, tourism operators that have to suspend water recreation, and governments that have to pay for water-quality treatment and improvement (Bureau d'audiences publiques sur l'environnement (BAPE), 2003). Without healthy conditions in soil and water, multiple industries can suffer in different ways due to the same environmental factors.

## 2.9 Disadvantages of Composting Toilets

The disadvantages of using composting toilets come in the form of maintenance, costs and policy barriers.

### 2.9.1 Consequence of Mistakes

One of the first and most unattractive disadvantages of a composting toilet is when the toilet is not managed properly or understood, the consequences can be filthy. A composting pile that lacks any of the aforementioned essentials (moisture content, size and temperature, C/N ratio and aeration) can result in anaerobic conditions. These conditions "produce very little heat as most of the energy in the organic matter is in the methane produced (Verougstraete, Nyns, Naveau, & Gasser, 1985)." This results in low pile temperatures, and foul smells (Leonard & Plumley, 1979; Oremland, 1988).

The leachate that gathers at the bottom of composting receptacles is an unpleasant variable in composting toilets. Generally, airflow is achieved in composting toilet systems that evaporates liquid while excess liquid is drained when needed. Liquid accumulation is still mentioned as a common problem in the literature of compost toilets (Crennan, 1992b; Enferadi, 1981; Stoner, 1977). "Auxiliary heating or installation of electric fans is usually advocated as a solution, if occasional drainage is not feasible (Chapman, 1994)." The problem of liquid accumulation has been noted in one of the most common commercial composting systems, the Clivus Multrum. Accumulated liquid immerses the pile for extended periods of time, causing anaerobic conditions. Foul odors follow when an anaerobic state is created. Other commercial systems have been designed, such as the Soltran, to combat this problem. A separate evaporate tank is used to evaporate the excess liquid when electricity is not available (Ely & Spencer, 1978).

### 2.9.2 Upfront Costs

As stated previously under the advantages of composting toilets, the initial costs can be much higher than that of a conventional toilet. When installing a septic system, the financial difference is less. However, when moving into a residence where a septic system has been previously installed, buying a new toilet, if desired, is much cheaper than buying a composting toilet. The upfront costs of a composting toilet can be intimidating when coupled with new maintenance requirements and a new system that requires slight lifestyle adjustments. When viewing composting toilets in short-term finances, dry sanitation practices are daunting. Costs of composting toilets are much higher than the average cost of a conventional toilet when only taking short-term finances into account. On-site treatment of waste requires a long process of applications and providing construction plans and sanitary analyses that can be a barrier to residential composters and public service providers. A required graywater system to handle water used for hand washing or any other action in a residence or public restroom can be a costly aspect as this requires more industrial and financial investment than working with existing conventional water toilet systems already in place.

The struggle to find consistent policy regarding composting toilets creates difficulties in searching for financial aid to pursue a sustainable dry sanitation project. Lalander et al. (2013) notes "one contributing factor in the lack of such treatment systems is the lack of economic incentives for stakeholders throughout the service chain (Lalander et al., 2013)." Dry sanitation is a heavy cost at the beginning of a project, and the lack of financial aid and foresight of financial savings, these projects have trouble beginning or succeeding.

### 2.9.3 Policy of Composting Toilets

Composting toilets require licenses and inspections in order to be used as alternatives to conventional toilets connected to a septic system. "Without the benefit of high operating temperatures in compost toilets, there is understandable reluctance, on the part of health authorities, to approve the use of compost toilets for use in the home (they are considered a cesspool). This attitude is changing (Riggle, 1990)."

The policy requirements vary from country to country and from state or territory within one country. The lack of policy for composting toilets has resulted in failed projects and difficult for businesses and citizens to implement dry sanitation systems. There is a need for supportive policy of composting toilets that does not heavily burden a consumer interested in sustainable life choices. Canada, Mexico, Australia, Sweden and through Europe are some of the developed countries with multiple case studies, research and projects showing support and development of composting toilets in residential and urban locations (Cordova & Knuth, 2005; GHD, 2003; **?**). In countries such as the US with so many individual states and local regulations, composting toilets vary in acceptance and processes of approval.

GHD, formerly known as Gutteridge Haskins & Davey, approached an installation project of composting toilets in an apartment complex featuring 12 apartments with multiple floors as a feasibility case study. In their 2003 project, they explored the required policies to install composting toilets for large-scale use:

> "Composting toilets and waterless urinals have been installed in a relatively large number of public amenities, private houses and institutional buildings in Australia and there is an Australian Standard covering their designThe proposed apartment site is in the area of City West Water and negotiation on headwords charges and sewage rates will be necessary. No particular barriers have been identified, and several councils and water authorities in Victoria have now approved or are considering applications for composting toilets within sewered areas. Planning and building approval will be required and compliance with the Australian Standard should be sufficient to gain approval (GHD, 2003)."

Approval of an on-site disposal system of residues required forethought and organization, but did not prove to be a barrier. Residues must be tested and meet EPA guidelines. Transportation of compost and urine to agricultural land was not specified in the policy and regulation at the time of the project (GHD, 2003). The installation of composting toilets in Australia still requires organization and effort to understand required applications, but it shows promise and acceptance of dry sanitation practices, making sustainable choices easier to parties interested.

The Environmental Health Directorate of the Department of Health of Western Australia outlines a step-by-step process to understand the application process to install composting toilets. The treatment of sewage via composting toilets must be in accordance with the Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974. An application is required whenever an attempt is made to install an on-site wastewater disposal system. Approval must be acquired before use or the system will not pass. First, the public health application must be completed and submitted, provided online. Second, application fees must be paid for local government approval ($113) and the Department of Health ($35). Third, a detailed summary of technical information about the system must be submitted with the application (of Western Australia, 2011).

The step of providing technical information appears intensive and requires in depth knowledge of the system and its composting products, but could be completed with the aid of the company responsible for the production of the proposed commercial composting toilet. Technical information needed includes the nature of the project, describing information on the proposed project, site and soil assessment, plans and specifications. A system plan is required to show system drawings, arrangement of tanks, capacity of components and other accessories. The applicant must provide a site plan and building plan showing the location of all buildings, swimming pools, storm water drains, and water courses, topographical features, and more. The design and details of the toilet system are required such as the type of system, trade name, manufacturer name, and the design capacity of the system. A description of the treatment process is required showing a flow diagram during the treatment process, details of the pre-treatment system, and possible disinfection method. Finally, the flow and load of effluent, effluent quality, and land application or reuse system must be provided. At this point in the application, a maintenance agreement is signed to assure responsibility of the toilet, certified engineering specifications are attached to the application, and compliance with the Government Sewerage Policy is assured. The combination of information required for the third step in the approval for the Department of Health of Western Australia is intensive, but composting toilets have been installed successfully in both rural and urban settings (of Western Australia, 2011).

Government documents published describing application processes are readily found in a literature search for Australia, but more difficult to find in regards to the United States. This may be due to the varying differences in waste management in every state, and local laws of counties. “Florida, for example, encourages the use of composting toilets while Nevada doesnt approve them at all. Most states have vague regulations somewhere in between (EcoBrooklyn Inc., 2012)." Due to the differences in local laws and levels of acceptance throughout the United States, Van der Ryn (1978) provides general guidance steps to prepare for installing a composting toilet: "1) Be prepared to present test data providing positive soil percolation. Authorities may require proof of backup capability for a conventional system. 2) Show an understanding of the basic system operation and existing data. 3) Prepare an outline of maintenance procedures. 4) Offer to present data from an approved laboratory testing for fecal coliform, salmonella and parasite ova (Van der Ryn, 1978)."

Meeting requirements in the United States is feasible when using a composting system that is certified by an international standard. It is possible to personally construct a composting toilet system at a personal residence, but use in urban or large-scale areas entails strict standards. "The leading commercial composting toilet systems are certified under the National Sanitation Foundations Standard 41, a requirement by many state and local governments (EcoBrooklyn Inc., 2012)." Using composting created by toilet systems as soil conditioner or fertilizer also varies greatly between local governments.

### 2.9.4 Required Grey-Water System

Composting toilet systems do not require a conventional plumbing system, but water is still needed for daily activities such as bathing, laundry, cooking, drinking, etc. As a result, "composting toilet systems must be used in conjunction with a graywater system in most circumstances (United States Environmental Protection Agency (US EPA), 1999)." According to the Department of Environmental Protection of Massachusetts, there are three approval options for graywater systems: remedial use, general use for new construction, and piloting approvals. Once establishing which type of graywater system is best for the location of the composting toilet, the suited application may be filed. The use of a graywater system is becoming more common in rural as well as urban areas, but the addition of installing a graywater system is another disadvantage to homeowners and service providers interested in composting toilets.

## 2.10 Successfully Implemented Composting Toilets

Composting toilets have been implemented successfully around the world. Commercial composting toilets have been seen in locations outside of residences such as "cabins, lodges and resorts, environmental education centres, permaculture centres, camping grounds, tourist destinations, national parks and wildlife services, Aboriginal communities, and schools and universities (Clivus Multrum Australia, 2013)." Impressive examples have been found in large-scale urban use in the United States, where policy is stricter in allowing alternative sanitation systems. One urban location of composting toilets has been noted in New York; the Bronx Zoo. The Bronx Zoo is New York is the largest urban zoo in the United States. A 2006 project completed by the Bronx Zoo won the New York Constructions 2007 Eco Project of the Year for a restroom featuring composting toilets for the 2 million visitors received annually (Clivus Multrum, 2010). The designer, Edelman Sultan Knox Wood, successfully featured 14 foam-flush toilets and 4 waterless urinals contributing excrement to 10 large composters. A foam-flush composting toilet uses 6 ounces of water per use, resulting in the Bronx Zoo bathroom saving a total of 1 million gallons of water each year. A graywater and rainwater system is used that waters an ornamental garden using the water from sinks. All wastewater and compost is handled onsite. "The Eco Restroom at the Bronx Zoo replaced a failing septic system, avoided an expensive connection to the overburdened combined sewer system, prevented pollution to the nearby Bronx River (Clivus Multrum, 2010)." Of the 2 million annual visitors to the Bronx Zoo, 60% use this reconstructed, sustainable bathroom. The project stands as an educational tool for visitors, and as motivation for other projects willing to undergo the timely process.

## 2.11 Failed Composting Toilet Projects

Ideally, composting toilets are one of the most beneficial waste collection options possible. However, an ideal solution is not a guaranteed solution. Failed cases of composting toilets are not uncommon, and the effects are unpleasant and form negative impressions of alternative sanitation. Several research projects have assessed the efficacy of composting toilets (Crennan, 1992a, 1992b; Enferadi, 1981; Stoner, 1977). Failure to produce sanitary compost has been found as the result of: "poor design, overuse, insufficient maintenance, low temperatures, anaerobic conditions, and excessive urine (Holmqvist & Stenstrom, 2002; Matthews, 2000; Redlinger, Graham, Corella-Barud, & Avitia, 2001; Tønner-Klank, Møller, Forslund, & Dalsgaard, 2007; (WHO), 2006)."

A news report from British Colombia found two cases of failed composting toilets in universities and parks. "According to Patrick Graham, manager of parks capital projects for Metro Vancouver, three composting toilets piloted at Surrey's Tynehead Regional Park are not functioning correctly (Proctor, 2013)". Liquid was being evaporated by the fans installed, but the solid material showed no signs of decomposing and produced foul odors. Similarly, at B.C. Park, a Clivus Multrum unit failed to product sanitary compost. Don Mills, a representative of Clivus Multrum, claims that the unit would have worked with proper maintenance, addition of bulking agent and removal of solid material when needed. Mills claims that "obviously they're not operating the park with the aim of collecting the visitors' excreta so that it can be recycled. Their job is recreation – not recycling. So the ideal circumstance is that they don't have to have anybody spending any time taking care of a toilet system (Proctor, 2013)." In attempt to recover the composting toilets in B.C. Park, Geoff Hill, founder of Toilet Tech Solutions, analyzed the situation and commented that "one of the problems is that liquid and solid waste are not separated at source. As a result of mixing the two before the urine is screened out, ammonia in the feces rises to levels that cannot support the micro-organisms needed for the composting process (Proctor, 2013)." Whether the fault lies more with the users or producers, a failed composting toilet producing negative media affects choices of others to explore this alternative waste method.

In their research, Cordova and Knuth (2005) reveal operational problems with dry toilets in various regions of Mexico. Operational errors causing any dry toilet failures were linked to "user awareness, user training, technical support, cover material availability and/or end-product management (Cordova & Knuth, 2005)." Poor operational cases involved users with inadequate education of composting toilets, lacking technical support, and uncertainty as timing for emptying the dry toilet. Operational problems were found in both rural and urban programs (Cordova & Knuth, 2005). Cordovas research has shown that Mexico features some of the largest examples of dry sanitation in urban settings and use throughout the country. In face of many successes and a higher rate of dry toilet use, failures are still experienced and must be researched for improvement.

## 2.12 Barriers to Adoption of Composting Toilets in Urban and Suburban Settings

Barriers between composting toilets in urban and suburban areas form as a result of many variables. Previously discussed in this literature, social stigmas are created in regards to composting toilets from historical practices, a desire to be removed from personal excrement, cultural factors, religions factors, and previous experiences with human excrement. People may be deterred by the thought of handling human waste, when previous experiences allowed waterborne, instantaneous removal of excrement to be treated elsewhere. The risk of pathogenic transfer when maintaining composting toilets causes a social barrier as well as policy barrier.

Determining urban barriers is important as many problems with dry sanitation projects are noted in public facilities and larger, multi-story buildings. In Dr. Leonie Crennans research and experience, "it was primarily public facilities that experienced problems (Chapman, 1994; Crennan, 1992a)." Urban locations are home to dense populations creating difficulty in constructing waterless, sustainable toilets such as composting toilets.

Three types of barriers have been previously determined by Cordova and Knuth (2005) in their research in Mexico. Mexico provided an ideal study population due to its use of dry sanitation in large-scale urban settings. Dry sanitation toilets are readily seen with different climates, types of users and different models of toilets. An in-depth methodology to gather a balanced view of users composting toilets included detailed interviews with 50 practitioners and professionals in the field of dry sanitation in regions throughout Mexico. Analyses, videos and site visits determined the barriers were: "(a) those relating to the dry sanitation itself; (b) problems encountered when increasing the scales of program operation in both rural and urban context; and (c) issues specific to urban settings (Cordova & Knuth, 2005)."

These barrier types were further grouped into two categories based on the actions needed to address them; operational and structural. The operational sphere includes operational problems and those related to the sanitation operation such as program managers and community implementers. Examples from the operational sphere include user acceptance, toilet design and operation, urban issues (density), provisions of incomplete services, program operation and large scale of operation. The structural sphere includes "underlying constraints affecting dry sanitation programs that are not, for the most part, within the ability of individual program managers or community implementers to address." Examples from the structural sphere include lack of knowledge about dry sanitation, economic and professional resistance, political motivations, resistance to perpetuation of social inequities, program structural deficiencies and small, special experimental programs (Cordova & Knuth, 2005).

## 2.13 Method of Conducting Research

In past research of composting toilets, in-depth interviews and hands-on lab work have been utilized to analyze the functioning and efficiency of composting toilets, as well as the social and financial factors related to composting toilets (Anand & Apul, 2011; Cordova & Knuth, 2005; Fornes et al., 2012). While the previously establish barriers provided by Cordova and Knuth (2005) provide buildings blocks for this research, more data is needed with specific focus on the United States and the potential barriers to composting toilet adoption in urban and suburban locations in the. Building this area of research would benefit from the current thoughts, perspectives and the experiences of workers, researchers, service providers and consumers in the field of composting toilets with questions focused on the United States. Therefore, semi-structured Interviews with stakeholders in the field of composting toilets will be used to collect and analyze the different perspectives in an anonymous fashion.

Due to the international status of intended stakeholders, no physical lab is available to gather data; interviews will be conducted over the phone or distributed as an online survey. Both routes will follow the same question progression. In addition to feasibility and accommodating different time zones, the choice to gather data via interviews has been made to create a learning opportunity for the researcher and to acquire accurate, detailed data. This study will use interviews in triangulation with published documents of the participants and affiliated organizations to produce validated results. The primary results will be collected via telephone interviews and online surveys while the published material will offer insight and solidify the perception of a participant.

## 2.14 Interview Basics

Interviews can be likened to conversations. Specifically, interviews "are active interactions between two or more people, leading to negotiated, contextually based results (Haigh, 2008; Silverman, 1997)." The interviewer attempts to elicit honest responses to best answer the research questions without imposing personal bias. This research will use a standardized, open-ended interview in which each participant is asked the same, open-ended questions. "The standardized survey interview is designed for gathering data with which to measure the intentions, actions, and attitudes of large numbers of people, usually representative samples of the population being studied (Houtkoop-Steenstra, 2000)."

Interviews, in various forms, have frequently been used to gather qualitative data in social sciences (Cordova & Knuth, 2005; Creswell, 2009; Haigh, 2008). In the case of this research, interviewing experienced stakeholders in the field of composting toilets would be used to determine the barriers observed by the panel between composting toilets and large-scale use in urban and suburban locations. This topic includes a complex nature of topics such as social perceptions, policy, sanitation, budgets and maintenance, making the interview processes a favorable path to data collection.

Interviews allow for more freedom and detail in the answers of participants. The researcher is able to balance standardization and flexibility with questioning, and can be conducted over the phone to account for participants in various places (Creswell, 2009). Researchers who intend to use interviews as a primary form of data collection must be aware of associated limitations. Interviews can be a common choice for researchers as the approach to the process may seem easy and common sense, but without prior research to determine the goal and type of interview, the findings of the research will provide less meaning. The data will be collected over the phone instead of in the natural setting of composting toilets such as a lab, site of use, or in the office of the participant. Participants who come from various professional backgrounds create different levels of articulate and perceptive responses. The success of the interview heavily depends on the relationship of the researcher and interview participant. Qualitative research interviews flourish with a balanced rapport "casual and friendly, yet decisive and impersonal (Denzin & Lincoln, 1998; Haigh, 2008)."

## 2.15 Summary

This literature review of composting toilets provided information regarding basic knowledge of the topic. A history of human excreta management was provided to give a background of how composting toilets have evolved in society. Definitions of dry sanitation, a basic composting toilet and different types of composting toilet systems were provided along with graphic representations. The process of composting was described and how the process can be optimized. The dangers of composting toilets, mainly transfer of pathogens, was explored in details as to how they are transferred and practices in place to produce sanitary compost. Social stigmas of composting toilets were explored that slow the process of common acceptance of composting toilets. The advantages of composting toilets were listed. Composting toilets do not need water, which makes them a viable option to pursue now when water is a limited resource and must be used more wisely. Compost acts as a soil conditioner to return nutrients to the soil that is left in human excreta. When treated with waterborne sanitation techniques, nutrients are lost and the nutrient cycle is broken. The disadvantages of composting toilets were discussed including their high initial cost, the grotesque consequences that accompany poor maintenance of a composting toilet, poor policies in place for alternative sanitation practices, and the requirement of a grey-water system. Successful composting toilet examples were provided followed by experienced failures around the world. Previous research was shown that found barriers between composting toilets and large-scale public use. Finally, the methodology to be used for this thesis was introduced. Interviews with stakeholders about the adoption of composting toilets into urban and suburban use in the United States were determined as the best choice of data collection. This method can make the best contribution available research in this field.

# CHAPTER 3. METHODOLOGY

This chapter contains specific details about the methodology conducted for this thesis project.

## 3.1 Sampling Interview Participants

According to Creswell (2009), "The idea behind qualitative research is to purposefully select participants or sites (or documents or visual material) that will best help the researcher understand the problem and the research question." The interview participants were individuals from different, important sectors relating to composting toilets use in communities. The literature review provided potential stakeholders by noting cited names in research, interviewed consumers, published writings of opinion leaders on the topic of self-made composting toilets or simply explaining or encouraging their use. To clarify, an opinion leader is a "member of the social system in which they exert their influence (Rogers, 1995)." The sample was created from these groups that comprise the stakeholders in the field of composting toilets. After each participant was contacted and offered the opportunity to be interviewed, all willing individuals make up the sample.

Participants who agreed to take part agree to commit 20-30 minutes of their time to take part in an interview over the phone. Panel members that were invited to join the study were included but are not limited to: (1) Researchers who have taken part in past projects of constructing and implementing composting toilets in various projects, (2) Opinion leaders in the field of composting toilets with research and hands-on experience, (3) City planners and architects involved with the decision making process of waste management and what types of systems to be used, and (4) City council members involved with policy making. Some stakeholders have more control or weight in decision-making in the future of composting toilets than other stakeholders.

These groups were chosen to comprise the sample because they each offered something different, but essential to the progress of composting toilets. Though personal details were not recorded in the published form of this research, summaries of how many participants and their represented backgrounds will be noted. When researching and approaching the topic of global water use, UNESCO considers the different stakeholders and individuals necessary to make changes:

> "Because of the implications of their decisions for water use, an understanding of water issues and of the support needed for investments, institutions, incentives, information and capacity inside what has traditionally been considered the water sector requires partner- ships between those responsible for the economy-wide benefits of water and those responsible for managing water (World Water Assessment Programme, 2009)."

The stakeholders who responded and took part in the research created a knowledgeable, purposeful sample.

## 3.2 Goals of Interviewing

The first goal of this research was to acquire accurate data relating to the barriers to adopting composting toilets into the United States. The beginning of the survey focused on basic information such as the level of experience with the stakeholders. Each person interviewed played an important in the current and future development of composting toilets, making their understanding and experience with composting toilets crucial. With the varied types of participants from researchers on the topic to policy makers of water boards, it was possible that a participant knew a great deal about composting toilets, but had never used one. It was also possible that a policy maker on a water treatment board knew little to nothing about composting toilets. The knowledge and experience of stakeholders was a possible barrier during the interview process.

The second goal of this research was to gain experience in moderating interviews and eliciting the required information. Conducting interviews is an art form that is not mastered after one project. This research provided the beginning of this researchers experience in interviewing, and will be useful in future, professional settings. "In the entire qualitative research process, the researcher keeps a focus on learning the meaning that the participants hold about the problem or issue, not the meaning that the researchers bring to the research or writers express in the literature (Creswell, 2009)."

## 3.3 Interview Process

Each participant received a contact email with the choice to participate. After a date was set, a phone call was made using publicly available contact information. The flow of questions investigated the complexities of the research question. The interviews covered 4 major discussion topics; the stakeholders perceptions of barriers of the adoption of composting toilets, the barriers in urban and suburban locations, the differences and similarities between the location types, and what project experiences of the stakeholders had taught them about the adoption process. The choice to specify urban and suburban locations was made to focus on the barriers of influential areas in the US. These factors lead to research by Cordova and Knuth (2005) as a prime candidate for guiding in coding barriers.

Interviews were recorded using TapeACall iPhone application. After the data was correctly transcribed to a Word document, the recordings were deleted. Any participants willing to offer their insight but unable to commit to an interview over the phone were given the option to complete the questionnaire on Qualtrics once provided with a link via email.

## 3.4 Data Analysis

Interviews produced sections of text rich with data. Understanding the context of the data, recognizing patterns, and properly coding the data are central to best answer the research question. To begin, during the interview, raw data was accompanied with marginal notes describing impressions and perceptions of participants responses. After each interview, a contact summary sheet was produced to record who was interviewed, the professional details and relationship to the composting toilet industry, the contribution(s) made towards the research question, and any suggestions that can be made to add to the next interview. This contact summary sheet used with the raw data will allow for initial coding of the text. These sheets will the first step in data reduction; “selecting, focusing, simplifying, abstracting, and transforming the data that appear in written-up field notes or transcriptions (Miles & Huberman, 1984).” This did not reduce the quality, but cut down the collected text to the most important highlights. The marginal notes, transcriptions of text, and data reduction helped to coding for further analysis.

According to Miles and Huberman (1984), “codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study.” In qualitative research, this can include perceptions, activities, and publications produced by the participants. This research started with the style of “In Vivo”, coding with the language of the participants, for the notes and primary documentation. After each interview with the creation of the contact summary sheet, “descriptive coding” was used to describe patterns seen from multiple participants (Saldana, 2009). At this stage of coding, past research on barriers to innovative technology adoption and composting toilets was consulted. if a descriptive code was similar to a barrier established in previous research, a new, validated code was created.

### 3.4.1 Software Analysis

This research used Excel to organize the participants, questions asked, the responses, and the resulting codes, patterns, and statistics. Graphics and formulas were used describe and illustrate findings based on participant responses and frequency of codes in responses.

## 3.5 Summary

In this chapter, the specifics of the interview process were described in more detail regarding the participants and their roles as stakeholders in the field of composting toilets. The construction of the questionnaire media and analysis software were communicated.

# CHAPTER 4. SUMMARY OF DATA

## 4.1 Methodology Deviations

Though at first it was proposed to collect data using a Delphi method, further thought suggested that semi-structured, open-ended interviews with each participant in a single round would decrease bias of responses and provide in-depth, detailed responses. The initial level of knowledge of stakeholders in the proposal also aimed to construct a survey for stakeholders of all levels of knowledge; from no knowledge to in-depth knowledge. After the change in data collection, from Delphi to interview, it was decided that stakeholders with in-depth, and/or expert knowledge would be best to pursue. This change in data collection and potential stakeholder background made choosing and contacting of participants a more selective process.

As a result of an interview data collection process, the change to interviewing has produced rich qualitative data with strong themes and patterns. The action of interviewing allowed standardized questions to be asked, as well as ask for further details when desired. The presence of an interviewer with the desire to learn about the topic encouraged stakeholders to explain in deep detail in response to questions, and provide background information that may not have occurred in an online Delphi study.

## 4.2 Participant Responses

Of the contact made with potential stakeholders, 18 responded and were able to make time for an interview. Interviews over the phone or Skype were possible with 15 participants, while three participants chose the online survey interview to best fit their schedule. Potential participants were researched, and a summary of their contributions and career path helped prove each participants validity and contribution to the research. Though participants were pursued with various backgrounds, 50% of stakeholders came from an education background. The remaining 9 participants were closely distributed between architects, technology developers, project leaders, NGOs, and promoters/manufacturers.

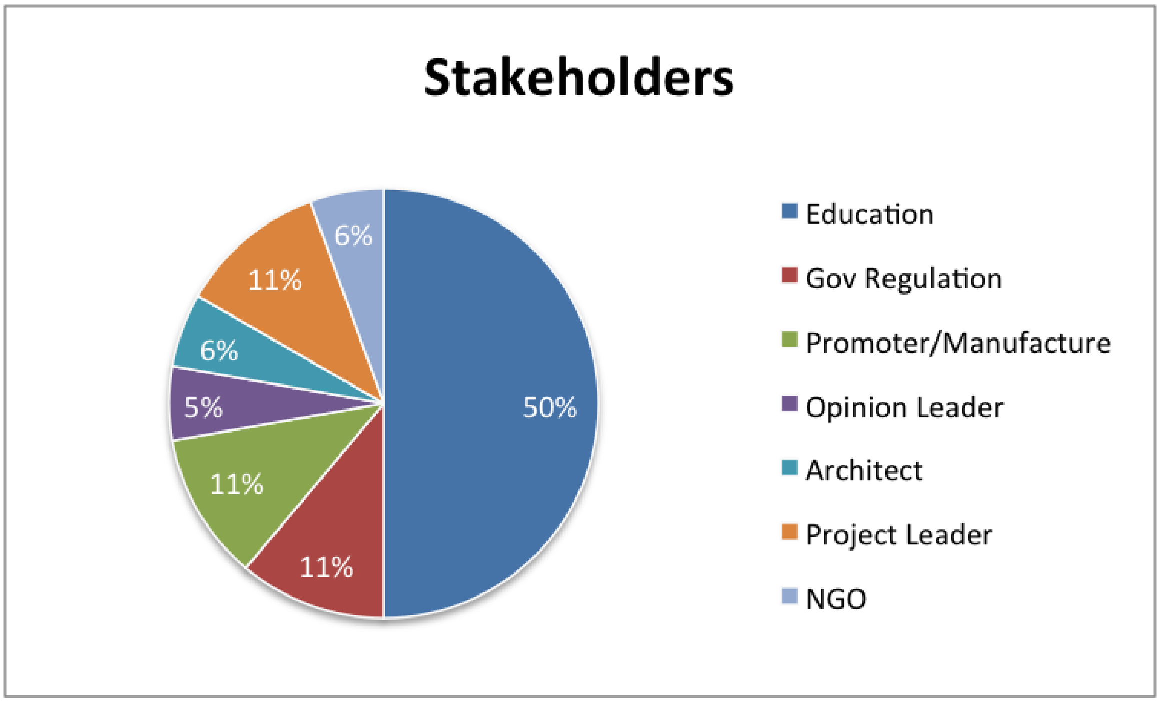


Figure 4.1. Stakeholders

Stakeholders with a primary background in education included various forms such as government licensed NGOs, academia, and workshops. Education covered a broad range of approaches, and the stakeholders with an education background had an affiliation for making time to disseminate knowledge. Education stakeholders were quick to respond to emails and provide contacts of colleagues as further contacts. Educators showed a special interest in the thesis project as the literature on composting toilets is rarely pursued by young researchers. In certain cases, this special interest translated into support through the entire data collection process, offering support and further literature to consider. Educators came from different focuses, offering considerations from multiple perspectives. Backgrounds have included engineering, government licensed organizations, NGOs, water, hygiene, diseases, environmental studies, and public health.

### 4.2.1 Stakeholder Knowledge

"*Do you have any knowledge of composting toilets? How do you define a composting toilet?*"

The first question investigated of the knowledge each participant had of composting toilets. With half of the stakeholders having a role in education of composting toilets, there was a low chance of any stakeholder not having knowledge of composting toilets. Only one stakeholder did not have a level of knowledge to comfortably answer the topics described in the survey. The first two questions of this respondents response were used for background information and to investigate the level of knowledge of stakeholders. Overall, 17 participants (94%) claimed to have knowledge of composting toilets. More so, the 17 participants had in-depth, experiential or academic knowledge of composting toilets.

After basic knowledge was established, the respondents were asked to explain how they would define a composting toilet, and state their level of agreement with the EPA definition of composting toilets. 16 participants provided responses of how to define composting toilets, and 15 participants provided responses on their analysis of the EPA definition. In order to analyze each definition, code, and compare, each definition was evaluated based on how the definition was framed, and key terms and phrases. Using the flow of the literature review and feedback of the interview participants, the basics of a composting toilet definition at the very least should contain three aspects: 1) First, the design of the toilet, which may include the structure, purpose and water use (or lack thereof), 2) The composting process with the specifics of controlled aerobic, thermophilic conditions to produce a sanitary product, and 3) The compost products purpose to close the nutrient loop as a beneficial soil amendment. Finally, the stance of the stakeholder on their agreement or disagreement with the definition of a composting toilet provided by the EPA was collected. Trends in responses appeared and were coded as “agree”, “agree with slight modification”, “neutral”, or “disagree”.

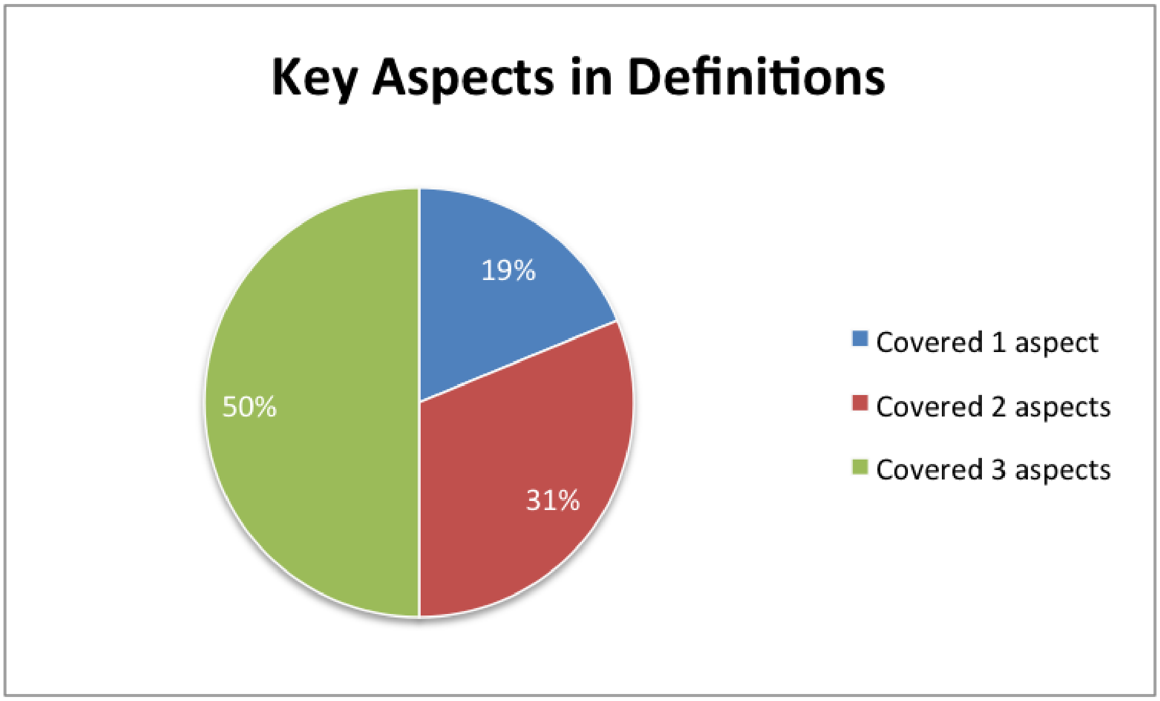


Figure 4.2. Key Aspects

Each definition was compared to the 3 key aspects determined from the literature review and data collection. The 16 definitions provided showed that half included all 3 aspects as shown in Figure 4.2.

Figure 4.3 displays the most popular aspects of the participants definitions were design and the composting product; both mentioned in 13 separate definitions.

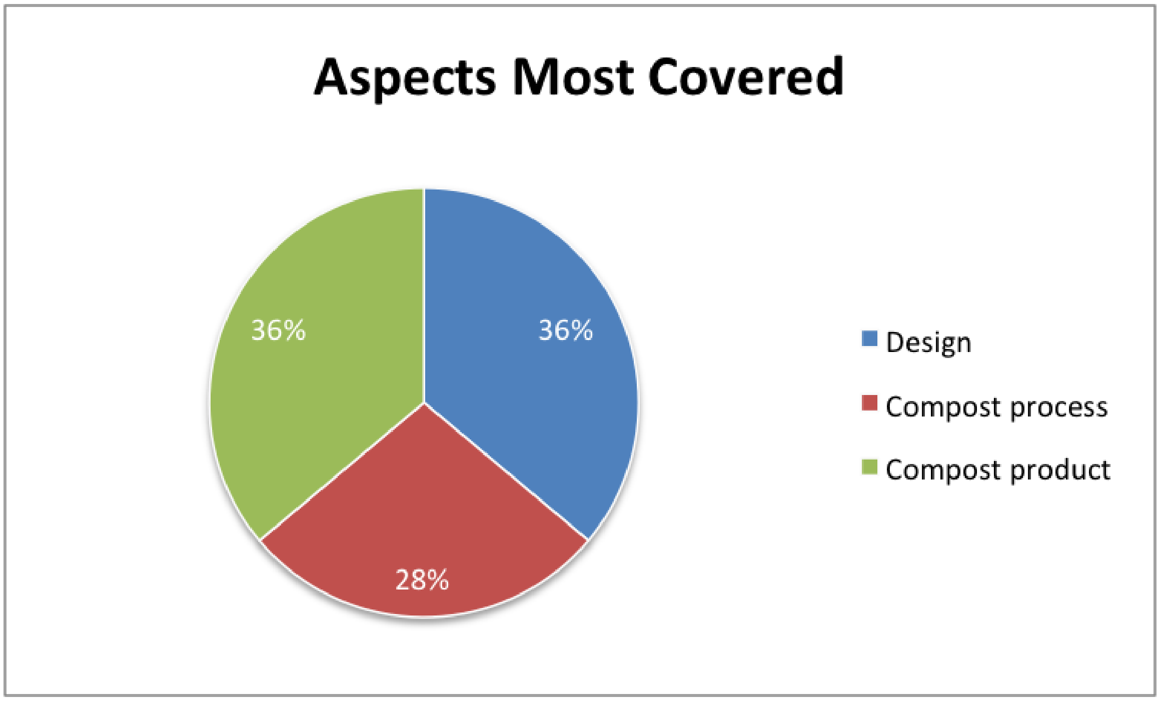


Figure 4.3. Aspects Most Covered

Though only slightly behind, the composting process was the key definition aspect mentioned in 10 different responses.

Finally, the level of agreement with the 1999 EPA definition of composting toilets showed that between those who fully agreed with the definition and those who would agree with slight modifications, 53% of participants agreed with the definition to a certain level.

The participants who chose a neutral stand point made comments on the EPA definition in both positive and negative manners including desired changes to the definition, but not enough to lean towards one side of the spectrum of agreement. Including the neutral opinions would make changes, a total of 87% or respondents wish to modify the EPA definition.

A fair point was made that agreement with a definition would require understanding the intended use of the toilet. The EPA definition does not explicitly

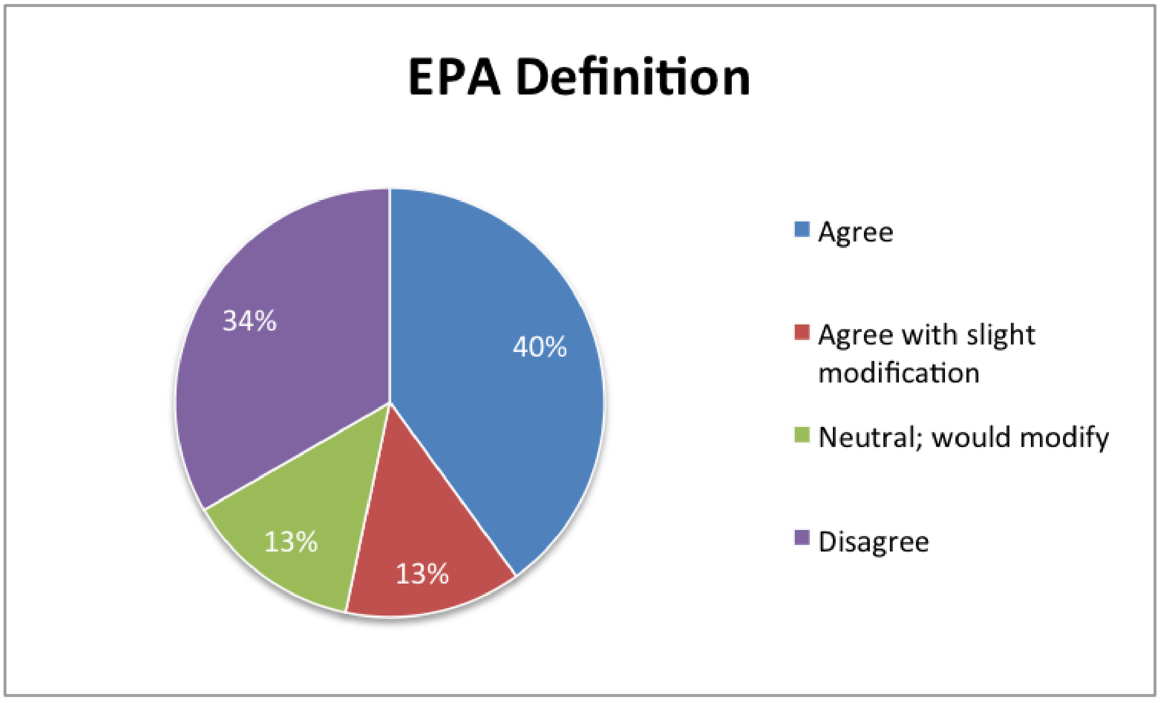


Figure 4.4. Level of Agreement with EPA definition

state the purpose composting toilets in their definition. Those who disagreed with the definition provided by the EPA did so with comments to improve the definition, and in some cases expressing a great distaste for the choice of terminology, excluding an explanation of the compost process, and use of end product.

### 4.2.2 Participant User Experience

"*Have you ever used a composting toilet?*"

To determine the first-hand experience of composting toilet use in stakeholders, each stakeholder was asked if they had used a composting toilet in the past. This was the last question in the interview in which all 18 participants could provide responses. Of the 18 responses, 15 (83%) participants had used a composting toilet and 3 (17%) had not. One educator had yet to use a composting toilet in their academic research of composting toilets, and both regulators had not used a composting toilet before.

### 4.2.3 Average American Knowledge of Composting Toilets

*"On a scale of 1 to 5 with 1 meaning none and 5 meaning expert, how much knowledge does the average American have of composting toilets?"*

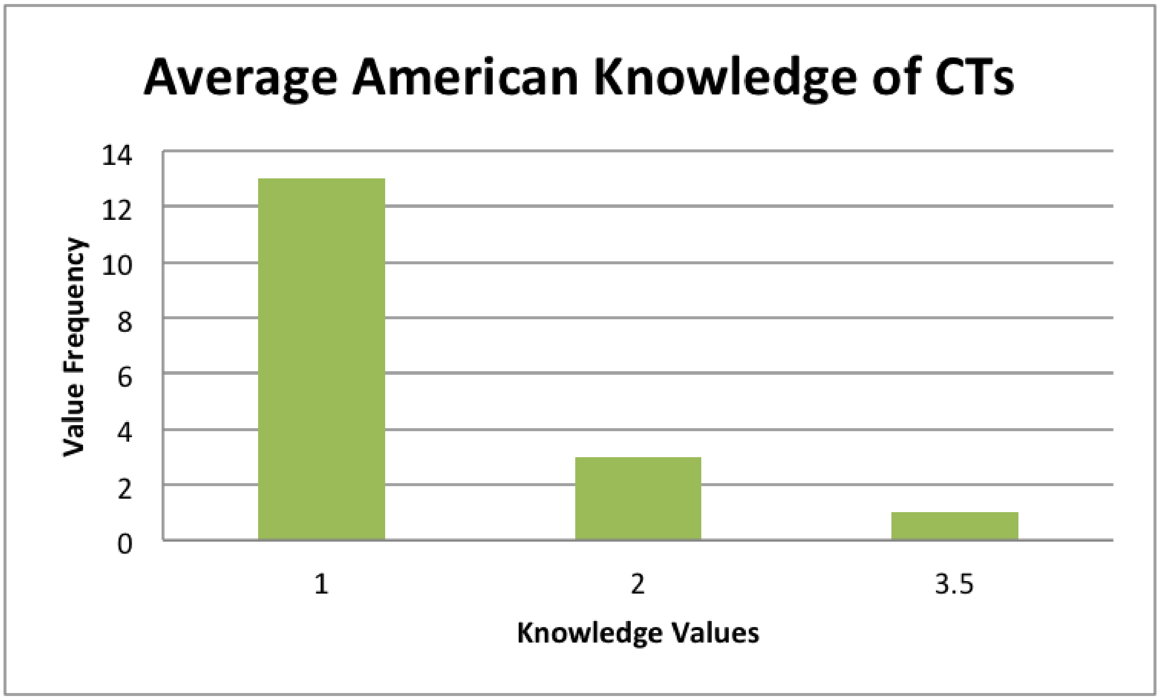


Figure 4.5. The Knowledge of the Average American of CTs

By the third question of the interview, only 17 participants were able to provide answers to the in-depth questions on composting toilets. Of the 17 participants, 17 provided responses. Using a 5-point Likert scale, participants ranked their perceptions of the average Americans knowledge of composting toilets. In one case, an outlier was determined due to basing knowledge off of one class-room experience. This outlier changed the mean of scores from 1.188 to 1.324.

Without the outlier, the mean score of the average understanding of composting toilets by the average American was 1.188, meaning very little to no knowledge of composting toilets.

### 4.2.4 Technology of Composting Toilets

"*Question 4: Is the technology behind composting toilets understandable by the average American?*"

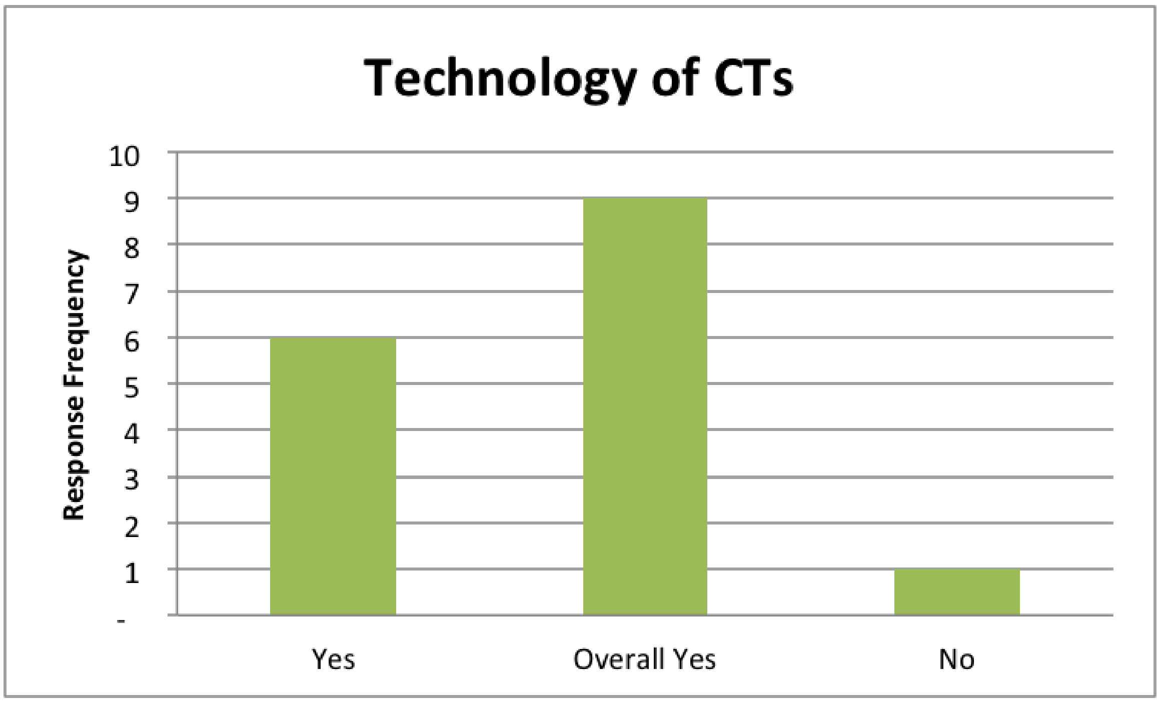


Figure 4.6. The Complexity of Composting Toilet Technology

A total of 16 participants gave responses to this question. Responses were coded as "yes," "overall yes," and "no". Responses coded as "yes" indicated that the technology, meaning the basic mechanics of using the toilet and required maintenance, would be approachable. An "overall yes" coded response indicated that use would be approachable as long as a clear explanation was given and the user understood the requirements of the toilet. A "no" coded response indicated that the technology and mechanics of a composting toilet were not understandable or approachable by the average American.

The majority (93.75%) of stakeholders interviewed found the technology to operate composting toilets to be understandable by the average American. While 37.50% found the technology to be understandable without question, 56.25% said the technology was conditionally understandable. The respondents who felt that the technology was conditionally understandable clarified that clear explanations must be accompanied with toilet, use, and maintenance. It was stated that as long as the composting process and creation of sanitary, healthy compost was not considered part of the technology, it was approachable by the average American.

### 4.2.5 The Barriers to Adoption of Composting Toilets

"*What are the barriers to adoption of composting toilets into use in the United States?*"

The full 17 participants responded to this question. Data was condensed and coded into 12 main barriers. Some of the barriers were coded based repeated terms and themes from data collection, and some barriers were share Cordova and Knuth (2005) research. Participants could name as many barriers as desired. No discussion of barriers occurred before this question in order to elicit answers true to participants thought process and not the survey. The total number of barriers mentioned post-coding were added to gain perspective on the frequency of the largest barriers to adoption.

The codes and explanation for each barrier is provided below:

- **Codes and Regulation** - building codes, plumbing codes, and regulation of waste treatment systems affecting the desire to implement a CT project. There are few accepted situations that allow the implementation of composting toilets. With lack of political motivation and the inability to

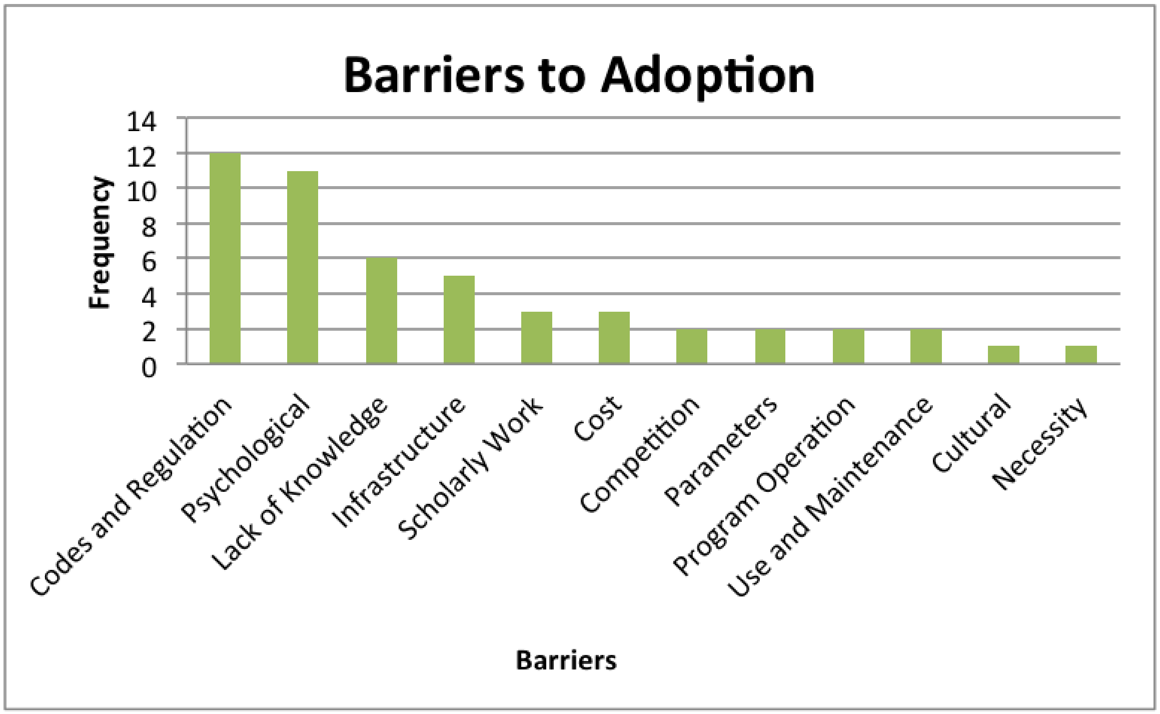


Figure 4.7. The Barriers to Adoption of Composting Toilets in the United States

compete with subsidies available for waterborne toilet systems, composting toilets are at a political disadvantage.

- **Psychological** the public perception, thoughts and mental states affecting the behavior towards the use of a composting toilet. Behavior is dictated by the psychology and attitudes of a person, therefore user acceptance requires on-going education, follow-ups and incentives to create true change in behavior.

- **Lack of knowledge** the lack of awareness of CTs, public education, level of knowledge of public and knowledge required of CTs, and required reeducation. The lack of knowledge of accurate knowledge on the topic leads to common misinformation on CTs. Lack of knowledge requires the education of regulators.

- **Infrastructure** the infrastructure that is required for successful CT projects is a combination of financial support, political support, maintenance and product services, end product collection services, and provision of incomplete services. Composting toilets meet economic and professional resistance such as the distaste for another type of waste disposal system that does not include the subsidized system of pipes and waterborne toilets. For urban locations, unique infrastructure issues may arise such as density, mobility and expectations of sanitation.

- **Scholarly Work** - When looking for work on successes and failures of different designs or work that uses composting toilets in the field (where, how, factors that determine those things, what are people thinking about them in the community), the only thing you can field is material that is published by NGOs and development institutions like UN and UNICEF, World Bank. Describing their own projects, own work to funders, people who understand one facet or orientation as dictated by their mission but dont have a mandate to deal with the sanitation of an entire community. The literature is narrow, so its hard to find actual successes and failures around the world.

- **Cost** CTs can be intimidating depending on the model due to upfront costs, cost of failure, dual cost of installation, and the questionable effect on home value.

- **Competition** - the existing appliances on the market, the lack of promotion of composting toilets and lack of funding; market, current subsidy provided for waterborne system. Currently, ssers don't pay the full cost of a septic, water-based system.

- **Parameters** - definitions (technical, sales, conflictions and correct distinctions), designs (measurements, materials, location), and purpose of the toilet.

- **Use and Maintenance** - To some, the concept of a composting toilet may be desired. The consumer may be see relative advantage of the composting toilet, but the maintenance may be misunderstood or the owner may lack commitment.
- **Cultural** - the learned practices and traditions directly related to a culture
- **Necessity** - the greater a need for a waterless toilet option, the greater chance that CTs would be considered. For example, California is experiencing its worst draught, which brings awareness to the public the amount of fresh water used in a toilet that could be used for other essential applications such as cleansing, agriculture, cooking, etc. Proposing the implementation of CTs becomes less opposed when it proposes solutions to multiple problems. This does not guarantee easier implementation, but it decreases the number of barriers that may be experienced.
- **Program Operation** - Barriers have arisen from the lack of small, special, experimental programs. Barring larger-scale of programs. Some projects have failed, producing unsanitary material due to insufficient training, lack of end-product management, and toilet malfunction. This leads to toilet abandonment and encourages negative views of CTs (Cordova & Knuth, 2005, p.249).

### 4.2.6 Most Problematic Barrier to Adoption

"*Of the barriers discussed, which do you think is the most problematic barrier to the adoption of these toilets?*"

Of the 17 participants, 2 requested to provide more than one barrier. This resulted in 20 barrier descriptions instead of 17. Though one answer was not provided from each stakeholder, the question narrowed down the choices significantly. to organize in order to determine the most problematic barrier according to the stakeholders. The percentages determined for this question were taking out of a sample group of 20, instead of 17.

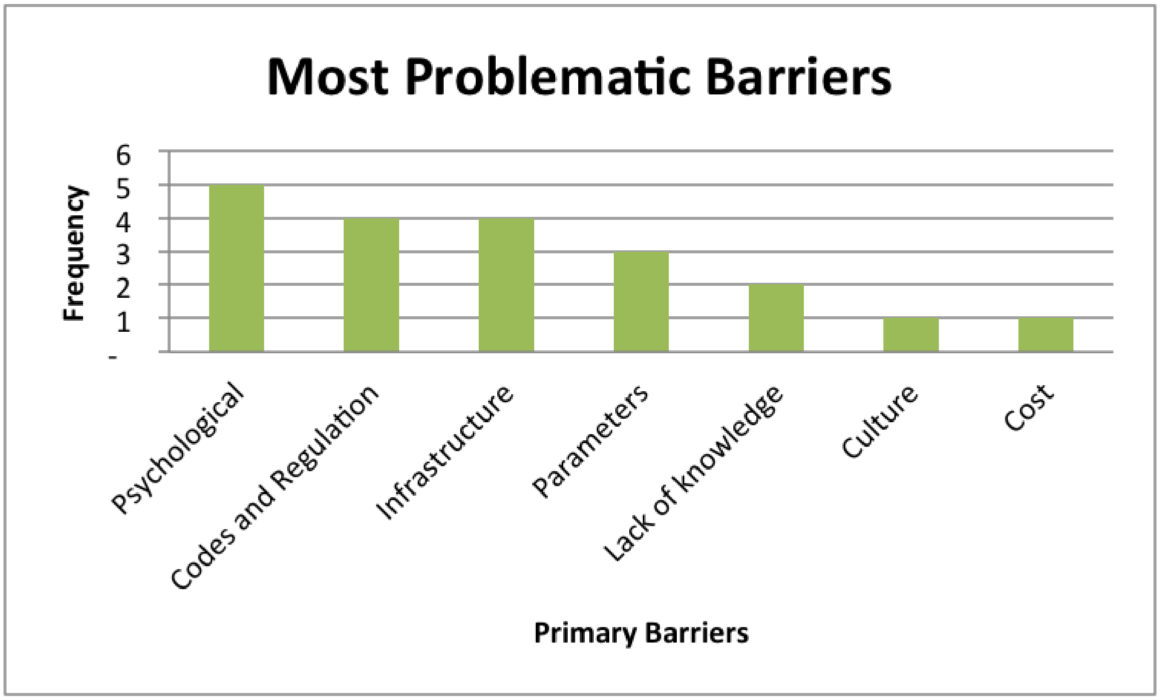


Figure 4.8. The Most Problematic Barriers to Adoption

With the question rephrased to guide participants to think of their previously stated barriers and choose the most problematic barrier to adoption, the psychological barrier outranked codes and regulation as well as infrastructure.

### 4.2.7 Barriers to Adoption in Urban and Suburban Locations

"*Do you think these barriers are issues in urban as well as suburban locations? Please explain any differences or similarities you understand between these location types.*"

This question focused on the barriers shared between urban and suburban locations. The question is further framed to include any similarities or differences the stakeholder may perceive between urban and suburban locations. 17 participants responded in two parts; a yes/no to the shared nature of barriers between urban and suburban locations, followed by a clarifying statement to explain any notable distinctions or similarities. 14 participants responded "yes", claiming the same barriers are experienced between urban and suburban locations, while 2 participants responded "no", and 1 responded "unsure".

The similarities and differences between the two locations types are listed below:

- **Similiarities**
  - Codes and regulation
  - Dependence on building infrastructure
  - Lack of collection service
- **Differences**
  - Space availability
  - Fertilizer options
  - Drives
    - Suburban
      - Why would they want to switch voluntarily?
      - What is gained by taking on the personal responsibility?
    - Urban
      - Where can one dispose of the compost in an urban area? They may throw the compost in the dumpster, but that defeats a large purpose of composting toilets. Without reuse options, the compost may be thrown away or be sold for LEED benefit.

### 4.2.8 Compatibility with Sanitation Values

"*Compatibility: On a scale of 1 to 5 with 1 meaning not and 5 meaning highly, how compatible is a composting toilet with the values and expectations of sanitation of the average American?*"

17 participants provided responses using the 5 point Likert scale. The mean value of was 2.4, and the mode of the data set was 1. Without prompting, many respondents chose values of .5 increments.

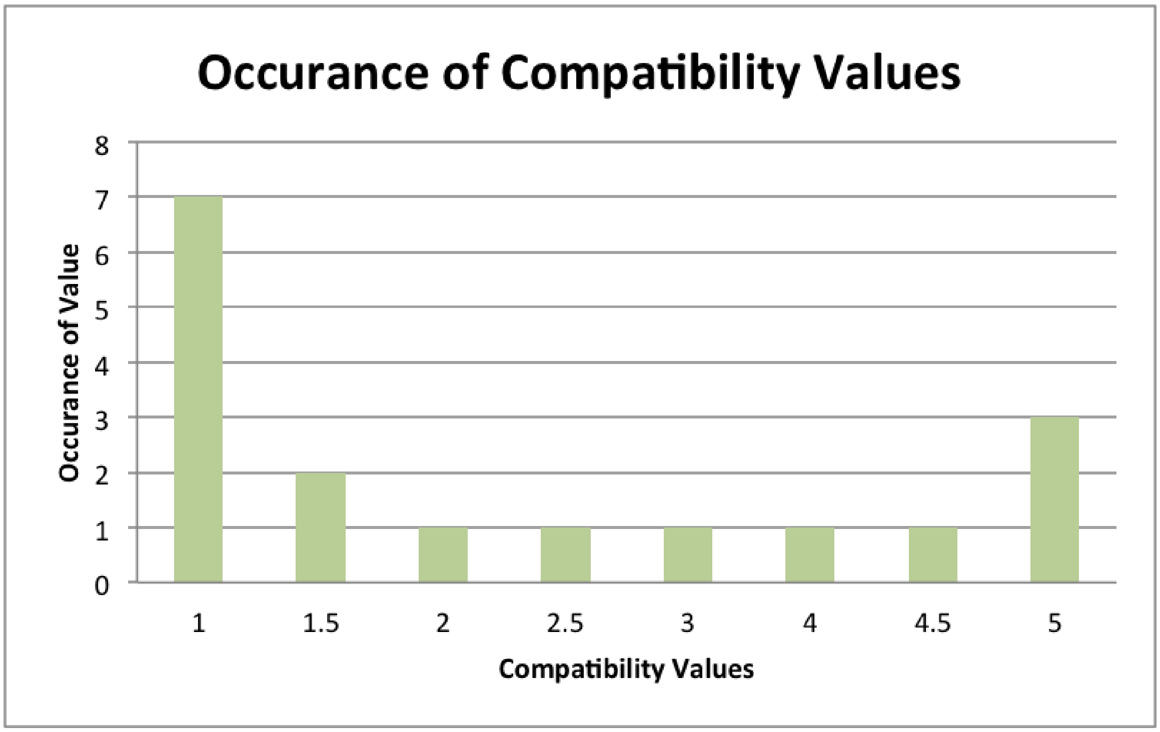


Figure 4.9. Compatibility of Composting Toilets

The most commonly chose value was 1, making up 41.2% of the recorded values. The second most popular choice was 5, making up 17.6% of the recorded values. Value choices vary based on nationality of respondents as well as the experience of each respondent with implementing or studying composting toilets.

### 4.2.9 Incentives for Adoption

*"Are incentives available for adopters of composting toilets? If so, in what form?"*

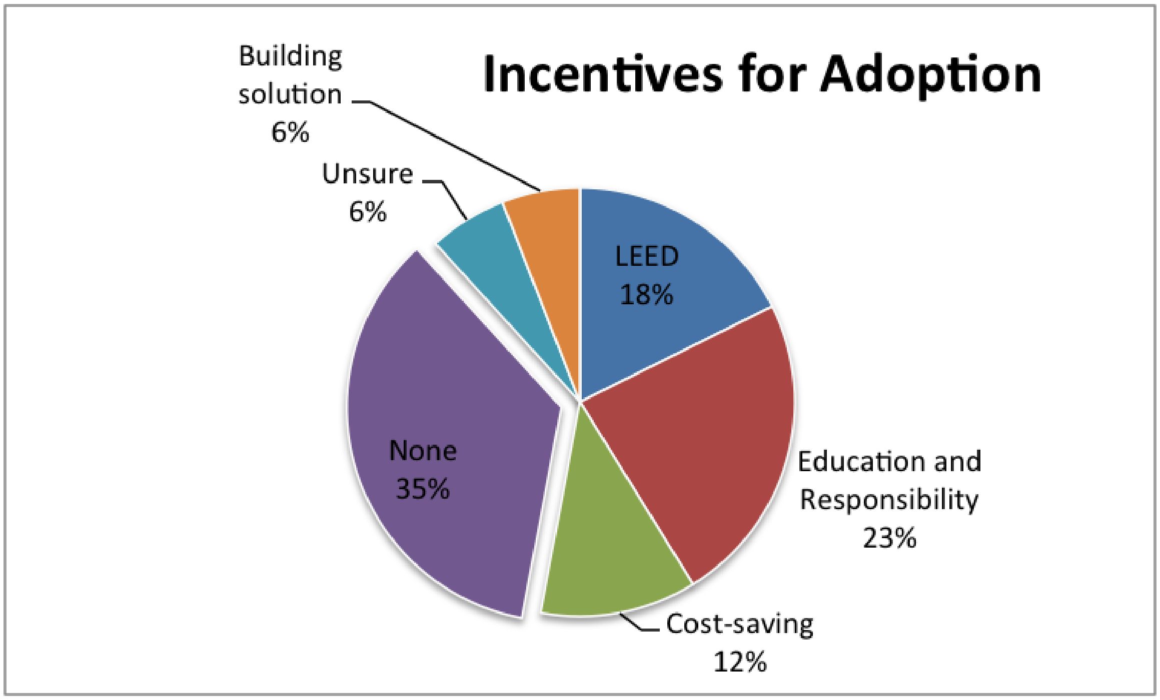


Figure 4.10. The Incentives for Adoption

17 participants provided responses. Though some stakeholders stated they were unsure of any existing incentives, some stakeholders provided up to three incentives, bringing the total number of incentives mentioned to 17 to create the descriptive statistics. 35.3% of the responses said that there were no incentives for adopters of composting toilets. Respondents who did provide an incentive listed possibilities as a fulfillment in education or responsibility, a solution to meet LEED standards, cost savings, or as a solution to a unique building problem. The most popularly stated incentive (23%) was the provision educational material and showing responsible actions.

### 4.2.10 Responsibility of Adoption

*"Who is primarily responsible for their adoption?"*

In this section we investigate the primary group that stakeholders felt had the largest amount of responsibility in the adoption of composting toilets in the United States.

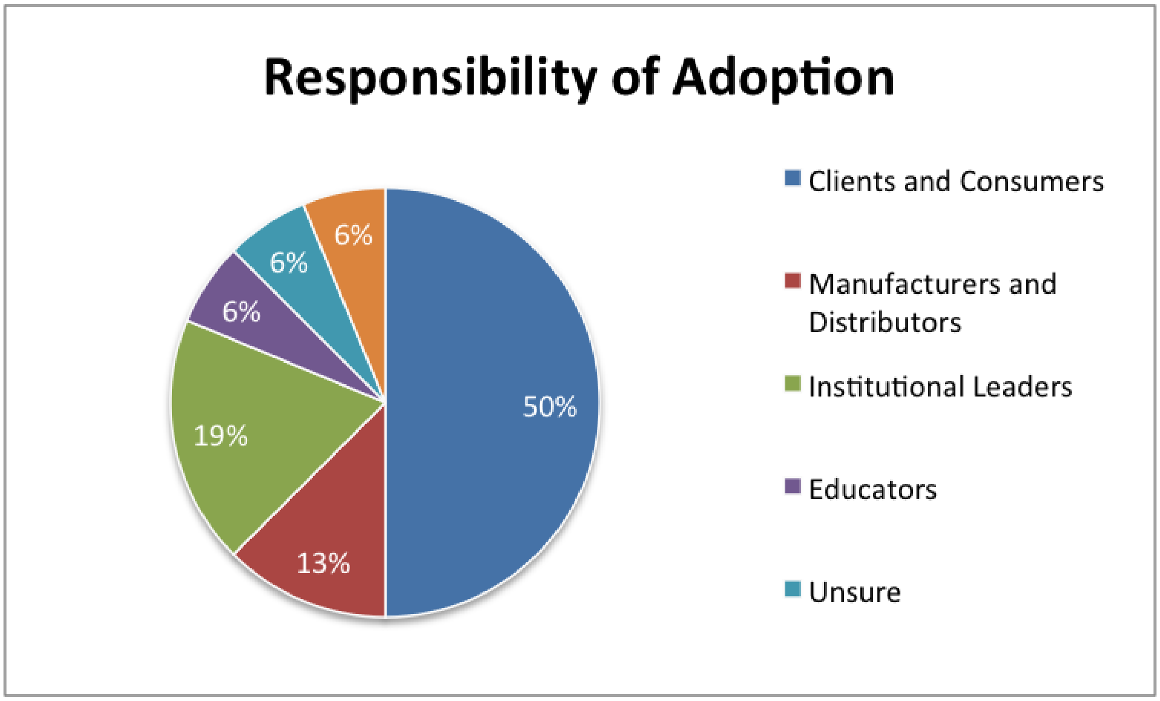


Figure 4.11. Primary Group Responsible for Adoption

Some of the groups mentioned were stakeholders who participated in the data collection; educators, manufacturers and distributors, and institutional leaders. A brief description of each type of group coded from the stakeholders:

- Clients and Consumers
  - The demand side of composting toilets largely falls on homeowners interested in sustainable responsibility, and clients involved in building projects. Clients may be involved in the design of the building, or any

way that gives power to choose a composting toilet as an on-site waste treatment system. This group can help to spread the adoption of composting toilets by bettering the technology and models with more consumer experience, increased revenue, and improving the observability of composting toilets.

- Manufacturers and Distributors
  - Manufacturers and distributors promote composting toilets, encourage sales, assure quality products, meet certification standards, and help customers with their toilets when possible.
- Institutional Leaders
  - Institutions in this case include law-making bodies, social, or educational organizations. Regulators and individuals in charge of creating law that oversees the allowance and product management of composting toilets.
- Educators
  - Educators include academic leaders, work shop operators, and research organizations. Educators collect and disseminate global knowledge and practices of composting toilets. Regulations differ between countries, so the global exchange of knowledge and ideas may benefit countries with stricter regulations such as the United States over time.
- Public Operators
  - Public operator is a general term used in this research for leaders in publicly or government funded projects such as parks, public bathrooms, shopping centers, events, etc.
- Unsure

– This does not refer to a group, but to the respondent being unsure as to which group is primarily responsible for adoption in the United States.

Figure 4.11 shows that half of the respondents perceive the group primarily responsible for adoption of composting toilets in the United States to be clients and consumers. Though clients and consumers is listed by respondents much more frequently than any other group, it is worth noting that institutional leaders are the second-most listed group as being responsible for adoption, listed at 19%.

### 4.2.11 Trialability of Composting Toilets

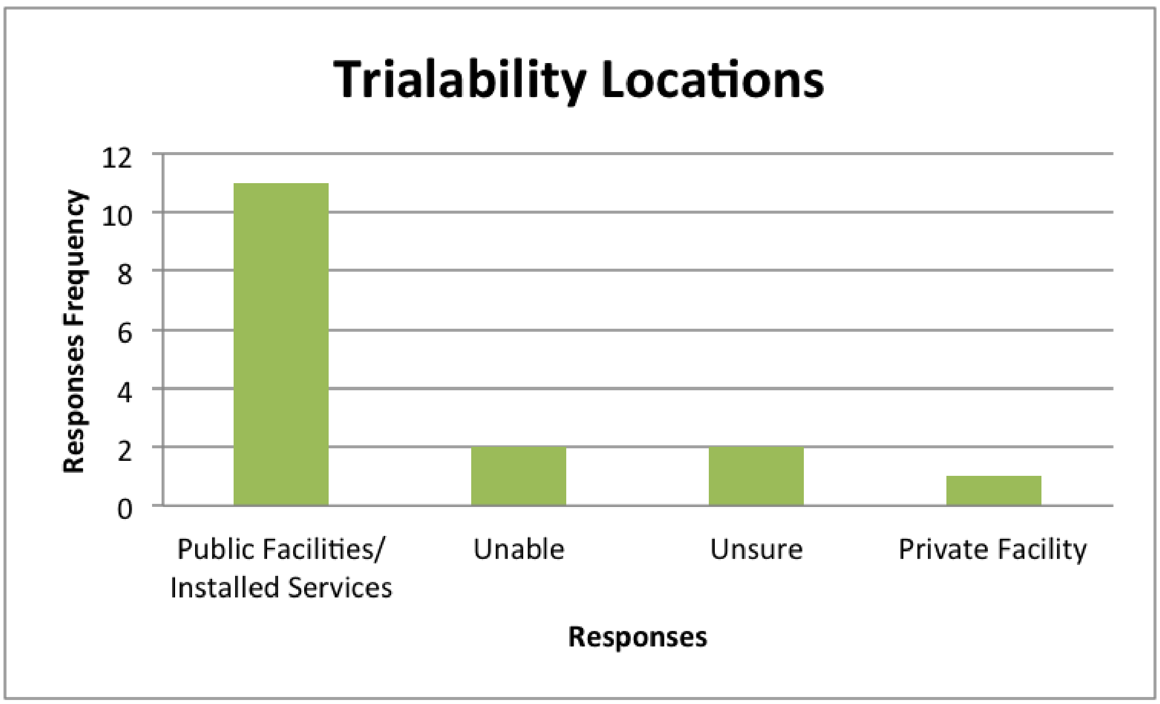


Figure 4.12. Locations to Trial Composting Toilets

The trialability of composting toilets in the United States was first coded using response of possible locations, and secondly by the attitude of 16 stakeholders responses. By noting the attitude of the response given by the stakeholder, the ability to trial composting toilets is understood in a more complete sense.

Figure 4.12 shows that 11 stakeholders (68.75%) said that the best, if not only, way to trial a composting toilet would be to find a public facility; a publicly or government-funded location that provides toilet facilities for visitors. The least popular option, making up 6.25% of responses, to trial a composting toilet listed by stakeholders was private facilities such as a friends home or neighbor who uses a composting toilet. Only 12.5% of stakeholders thought that there were no options to trial composting toilets, and 12.5% were not sure about the trialability.

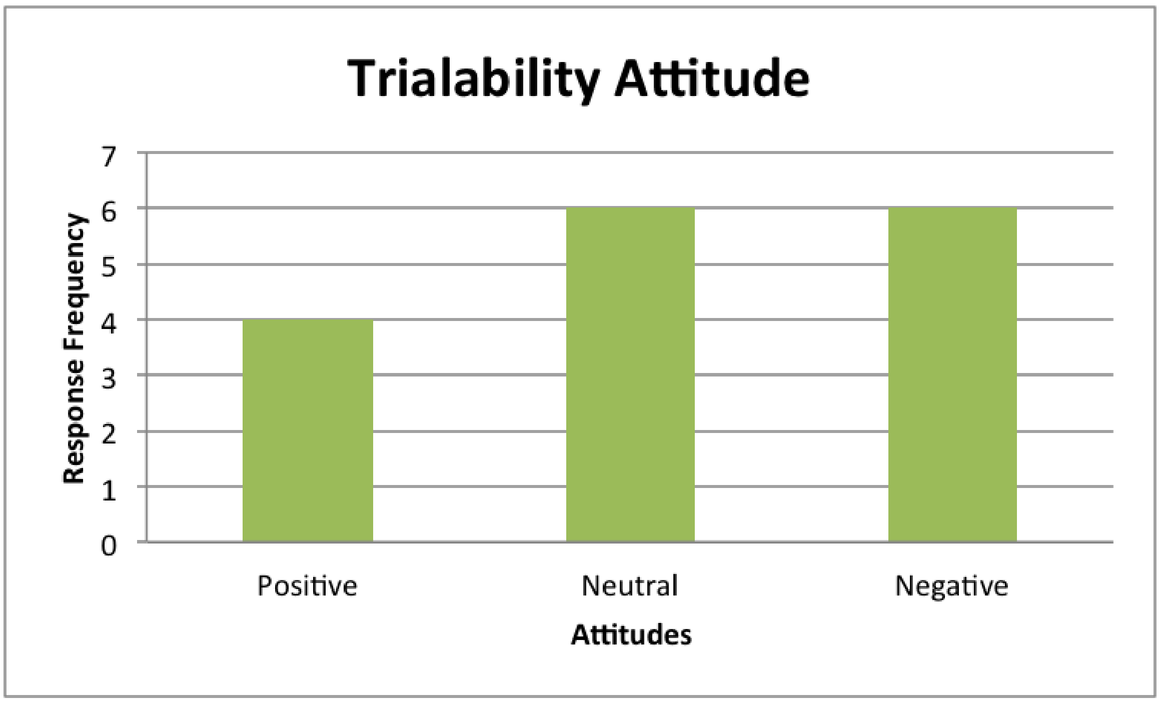


Figure 4.13. Attitude of Composting Toilet Trialability

Responses that were positive felt that a simple solution was finding then nearest public facility or installed service. Neutral responses showed hesitance before answering, but still provided responses in all but one case. Responses that were negative focused on the inaccessibility of composting toilets that can be trialed, and the effect this had on adoption. In all three attitude types, responses of trial locations were recorded, even with negative attitudes. Negative and neutral attitudes were the most common response types.

### 4.2.12 Role of Stakeholders

Upon contacting each potential participant, a general idea was understood for each participants role in the adoption of composting toilets. The perception of the stakeholders of their own roles was investigated to see if any differences existed between the researchers perspective of their roles, and the stakeholders perceptions.

Of the 16 respondents, 10 perceived themselves as only having one role in the adoption of composting toilets. 6 respondents felt they had two, related but different roles in the adoption. Of the 6 respondents who felt they had multiple roles, 3 replied their primary role was rooted in education. The role of an educator was not only an academic role, but in multiple cases included offering workshops, publishing writing, performing deeper research, technology improvement, training trainers, advising, and demonstrating.

The only difference in researcher perception and stakeholder perception was in one case of an organization offering workshops and education from professionals of different backgrounds with a focus on composting toilets. This case was listed as a non-governmental organization on the original contact sheet made by the researcher, but the stakeholder listed their role as an educator. However, the individual may be an educator representing the organization that acts as an NGO.

### 4.2.13 Societal Attitudes

"*Within the last decade, how have societal attitudes towards composting toilets helped or hindered their acceptance?*"

Of the 17 total participants, 14 were able to have a formulated opinion that summarized the last decade involving CTs. 3 participants were not sure about the

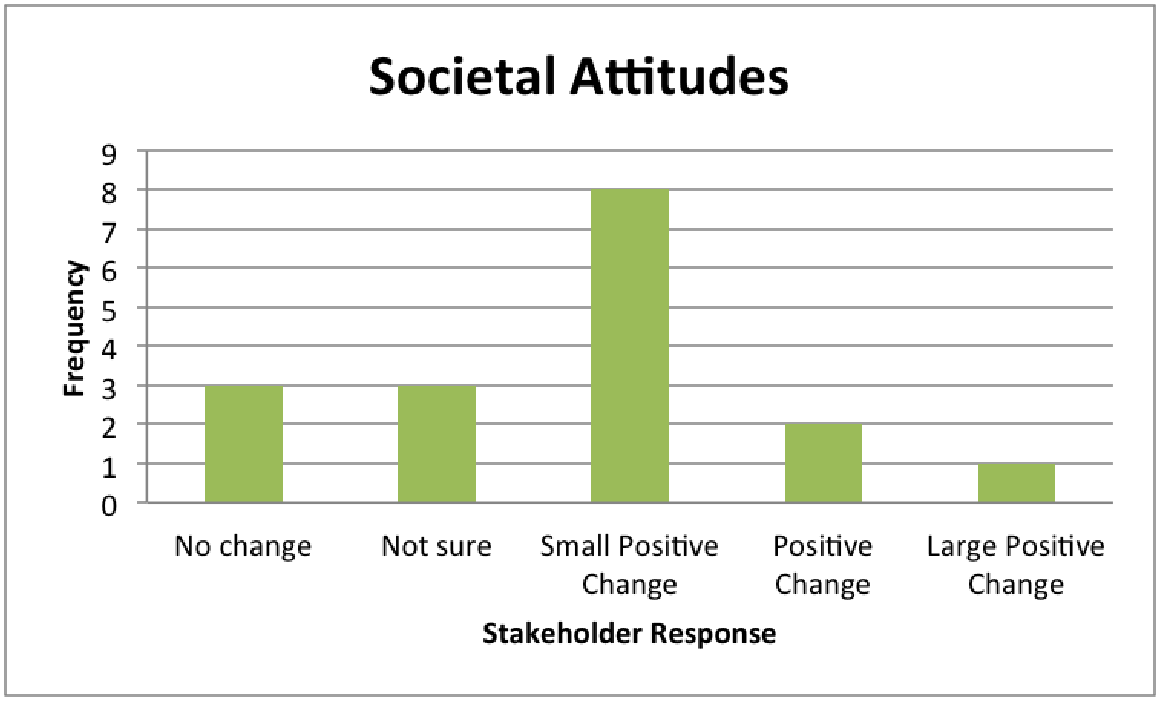


Figure 4.14. Perceived Societal Attitudes Regarding Composting Toilets

change in the last decade, or had not been involved in a related industry for a decade. Following Figure 4.14, stakeholders who felt that there was no change or were unsure each represented 18.75% of responses. 47.06% of stakeholders perceived a small but positive change in societal attitudes towards composting toilets. A distinct, positive change in societal attitudes was perceived by 12.5% of stakeholders. Lastly, a large, positive change over the last 10 years was only perceived by 6.25% of the stakeholders.

### 4.2.14 Policies and Adoption

"*How have existing governmental policies affected the adoption of composting toilets?*"

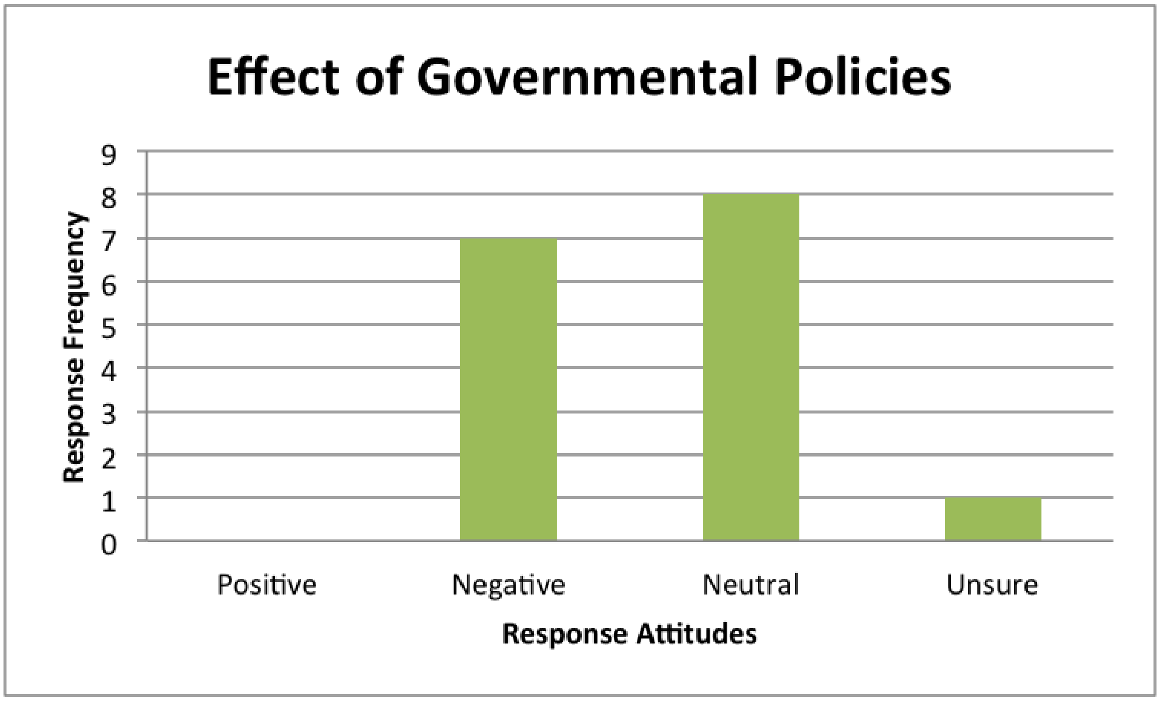


Figure 4.15. The Effect of Governmental Policies on Adoption

16 participants responded to their understanding of the effect that governmental policies had on the adoption of CTs. The attitudes of stakeholders responses were measured first. Negative attitudes during the sharing of a perspective were coded in 43.75% of responses. 50% of stakeholders had a neutral tone during their explanation, regardless of discussing difficulties or breakthroughs in CTs in legislation or regulation. The least common response, given by 6.25% or stakeholders, was unsure of a response that was well-rounded and accurate.

### 4.2.15 Technical Problems with Implementation

"*What technical aspects have posed problems with implementing composting toilets?*"

In response to this question, stakeholders helped to understand what the technical aspects of a composting toilet were, and which aspects caused the most

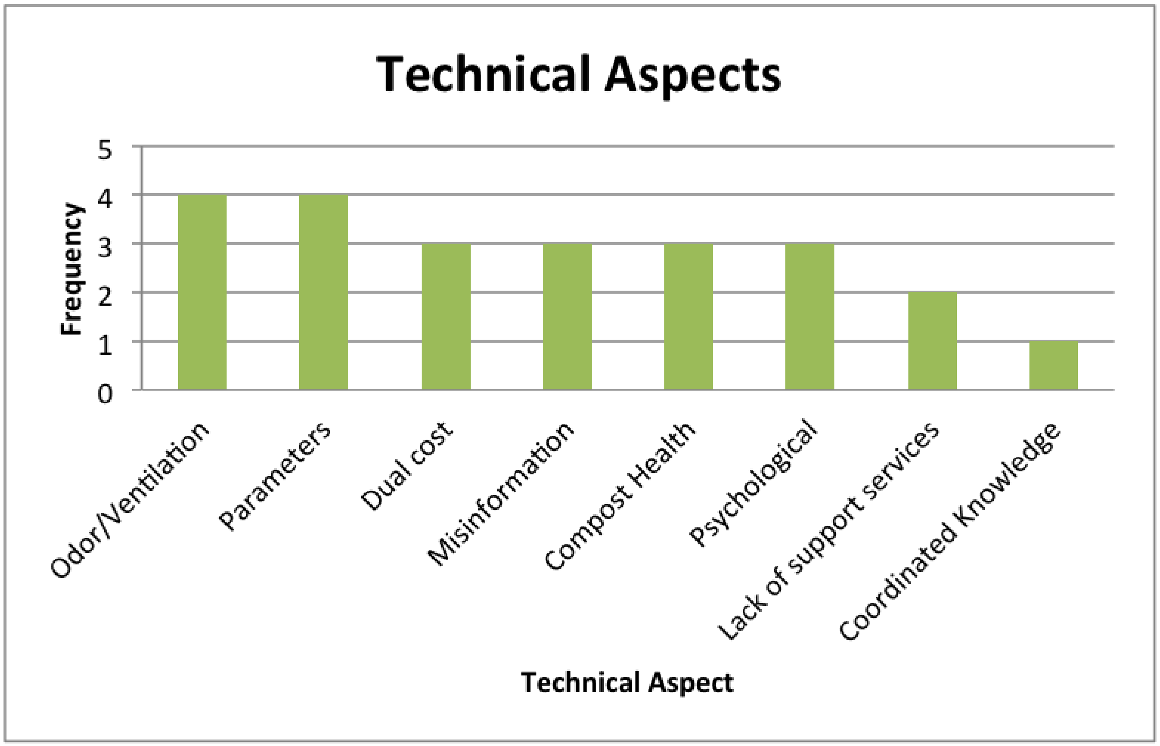


Figure 4.16. Technical Aspects of Composting Toilets

trouble with adoption in the United States. Between the 17 participants, 23 total responses were given, as 6 stakeholders provided more than one technical aspect. The results of stakeholder responses are seen in Figure 4.16, shown below:

The most common issues listed by stakeholders were coded and explained in the summary below:

- Odor/Ventilation - A common technical issue is the breaking of ventilation fans and or heating coils. This break leads to bad odor, as ventilation aides the composting process and decreases odor. In some cases, odor simply refers to models where a slight odor will happen at times. Unlike a waterborne toilet, odor may happen more commonly as result of maintenance of a CT through its life cycle.

- Parameters - Parameters include outlines of CTs such as standard designs, definitions, methods of maintenance, and accompanied education material for uses.
- Dual Cost - CTs accepted by legislation for use must have an NSF certification, which is approved by a third party. The accreditation process of a certification for the CT manufacturer increases production costs, which can transfer to the consumer. In states that require a connection to a local septic system, the purchase of a CT becomes a dual cost.
- Misinformation - A lack of standard parameters and uneducated promoters of CTs spreads poor understanding and misinformation on the topic.
- Compost Health - The balance of Carbon and Nitrogen in the compost can be difficult to monitor for new users, or users inexperienced with composting. If organic material or a bulking agent is required, the user must understand which material is required and the process of application.
- Psychological - Though not consistently thought to be technical, a small number of stakeholders emphasized that technical aspects are not barriers, rather the psychological response to the required maintenance.
- Lack of support services - Support services include the collection of composted material and maintenance help when needed. When purchasing a CT, easily accessible services to assist the user in any problems with using CTs can be difficult. No companies provide a full support system of toilet, maintenance, and collection of humus.
- Coordinated Knowledge - Related to parameters, coordinated knowledge includes the shared knowledge of CTs across all parties involved with the implementation of CTs. This knowledge must have standard parameters in order to avoid confusion and facilitate communication between groups involved.

4.2.16 Experience of Stakeholders in American Composting Toilet Projects

"*Have you ever been involved with a project implementing composting toilets in the US? If so, please describe the highlights of your experience and the result of adoption.*"

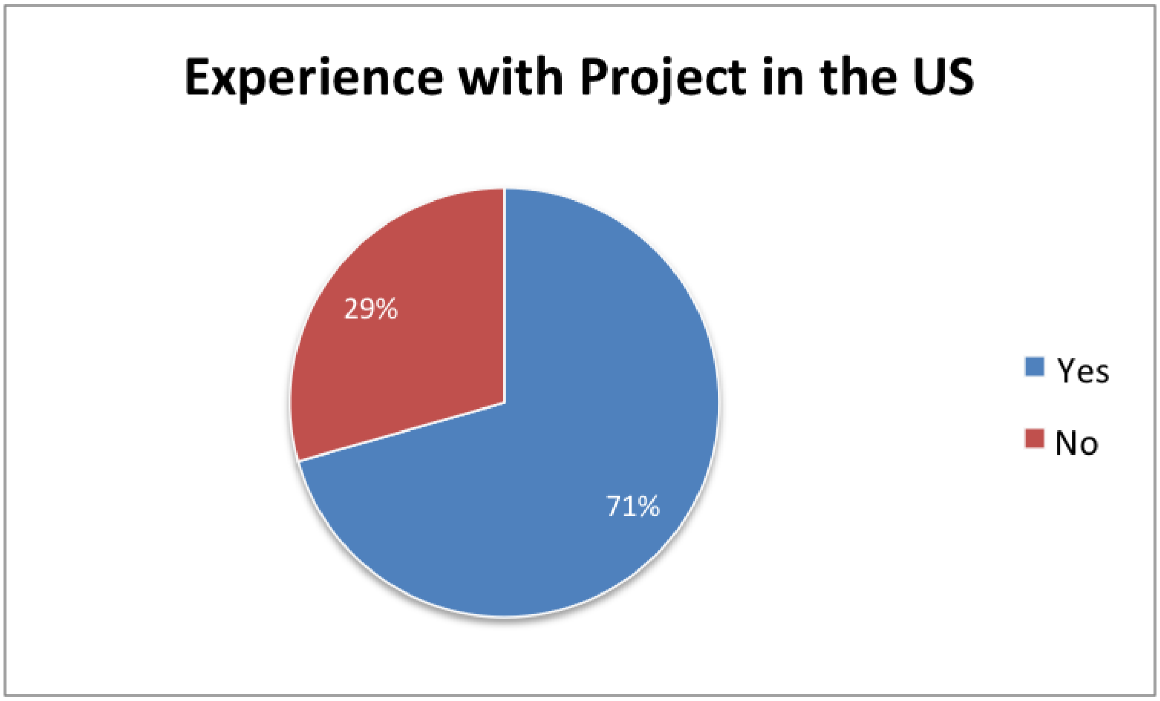


Figure 4.17. Experience of Stakeholders with US Projects

All 17 participants responded regarding their past experience with composting toilet projects in the United States. Stakeholders who had been involved with a project in the United States totaled at 12 people (71%) and those who had not been a part of a project in the US totaled at 5 (29%). 3 of the 5 stakeholders who had not been involved with a US project had experience with projects in other countries where legislation is more allowing. Of these 3 stakeholders, all had primary roles as educators, and one also fulfilled a secondary role as a project leader.

Though 12 stakeholders said they had experience in the US, only 10 provided descriptions of their project highlights. The experiences described from the participants were each different, resulting in only one pattern, "commitment and drive", found in 40% of the descriptive responses. Four different responses described the outcomes of projects relying on the reason for the project, and the long-term involvement of the community surrounding the project.


Figure 4.18. Stakeholders Highlighted Experiences

The description of "commitment and drive" will be described in this section, and the individual experiences with only one response each will be described in the following chapter to supplement in-depth discussion of the impact of stakeholder experience with CT projects. "Commitment and drive" refers to the parties, past, present and future, that would be involved in the project, their reason for approaching the project, and the long-term involvement. Commitment is required from all parties involved in the initial as well as future community members. With the addition of new community members, the situation may arise where a new resident disagrees with the toilet options and lifestyle required for maintenance, or not realize the commitment required. One stakeholder noted that in past projects, even with good intentions to start a project and educated guidance, some projects fell apart in the long-term due to lack of commitment to required maintenance, and failure to utilize the initially composted material.

The second and only other repeated code in stakeholder experience was "coordinated knowledge"; the importance of people involved in the conceptualization and application, and the knowledge held by all must be organized, clear, and follow coordinated standards. The steps to implement a CT project include multiple services during construction, accreditation, regulation, long-term maintenance, and end-product collection. Two stakeholders found the best projects were accomplished when everyone had experience using CTs, and were educated about the entire process. People who want the CTs to be installed actively take part and learn, contribute to the projects chance of success.

## 4.3 Summary

In this chapter, the summary of interview responses and codes were stated. The deviations of the research experienced from the original proposal were explained, as well as the effect of the changes on the final data collection process. Each question was listed with a summary of responses, and a graphical representation when needed. Further analysis will be provided in the following chapter.

# CHAPTER 5. DISCUSSION OF RESULTS

## 5.1 Introduction to Discussion

Using the result summary of stakeholder interviews and supporting detail from the literature review, a flow reflecting the drawn conclusions of this research will be the outline for this chapter. The conclusions will first be discussed regarding the adoption into the United States, and then the specifics of adoption into urban and suburban locations in the United States. After discussing the conclusions, the implications of the research will be discussed.

## 5.2 Five Characteristics of Innovation

Rogers (1995) method of predicting and analyzing the rate of adoption with five characteristics of an innovative technology are outlined in the second chapter of this research. The definitions and descriptions of each innovation characteristic are outlined in the first section of the literature review. With background literature and stakeholder input on composting toilets, the five characteristics of innovation can be analyzed in the case of CTs. With this analysis and later discussion of barriers, the slow rate of adoption can be better understood.

### 5.2.1 Relative Advantage

From a sustainability perspective, the relative advantage of composting toilets in comparison to a waterborne system is recognized. However, the key perspective in this research is the American population. Overall, there is little to no relative advantage of composting toilets to the average American. The duality of cost of a commercial, certified model shows little short-term benefit to a consumer unless there is need of a toilet without septic connection. CTs provide no social prestige if adopted, and may even confuse or repulse visitors. CTs also do not offer an increase in convenience; they increase user responsibility as opposed to flushing away everything. It is possible for a potential adopter in the United States to find a great relative advantage to using CTs, as the objectivity and perception of the adopter is the focus of relative advantage. However, this is not the common case for the average American.

### 5.2.2 Compatibility

The compatibility of CTs with the values and expectations of sanitation of the average American was found to be low. The current waterborne system for waste disposal in the States has created a large barrier in the perception of what constitutes sanitary toilet use. Though the use of CTs may not prove to be the largest barrier in regards to compatibility, the requirements of the owner to monitor and maintain the contents is highly incompatible with the average American.

### 5.2.3 Complexity

Though 93.75% of the participants felt that the technology behind a composting toilet was at least approachable overall by the average American, stakeholders emphasized that a clear explanation of composting toilets to the potential users is the key to success. However, the composting process is more complex, and reaches beyond the approachability of simply using CTs. In the case of the Bronx Zoo or a national park with implemented CTs under the care of another party, the average American is highly capable of understanding how to use a CT and the basic mechanics of how the toilet works. The complexity of CTs increases with the added responsibility of managing compost, bordering moderately complex as an innovative technology.

### 5.2.4 Trialability

The largest difficulty with trialing composting at public facilities or services using composting toilets is that requirement of the potential adopter to travel possibly great distances just to try a toilet. Most likely, an installed service using composting toilets would be a brick and mortar location selling composting toilets and allowing interested buyers to try them first in-store. This type of location is not common across the United States. The public facilities referenced generally to public parks and attractions that opted for a sustainable toilet option for a remote location, or to meet sustainable building standards. Popular destinations such as the Bronx Zoo are more common on the East Coast and West Coast, leaving many parts of the country with fewer, if any options to trial.

The attitudes regarding trialability showed that though 81.25% of participants provided an answer, the attitude towards the trialability was only positive to 25% of the respondents. A full understanding and experience can only be had with a long-term trial of a CT. In contrast, one response claimed that this process can be achieved quite easily due to a long track record in the US of setting up trials for novel technologies.

Trials before purchase of CTs not only gives a potential adopter a deeper understanding of what is to be expected, but also increases the chances of success with CT projects. Pilots of one or multiple CTs at a destination before making a larger commitment eases psychological fears and misunderstandings of CTs, gives the future community an idea of what to expect, and minimizes negative consequences in the case of rejection of the CTs.

### 5.2.5 Observability

Toilets, waterborne, waterless, or composting, are generally items kept in private. Projects with high observability include the Bronx Zoo and workshops such as the Greywater Project are the only cases in which the innovation can be easily seen, discussed, and understood. Even with a education-based projects and workshops, CTs are not displayed in constantly visible areas, resulting in low visibility.

### 5.2.6 Rate of Adoption

Rogers (1995) used these five characteristics of innovation to explain the different rates of adoption due to the perceptions of the innovation in question. In the case of CTs, the perception held by the average American suggests a slow, laborious rate of adoption. CT projects can still be successful and education can slowly spread with an increasing emphasis on sustainability in the US, but at a slow rate until these innovation characteristics are improved.

## 5.3 Barriers to Adoption

The barriers shown in Figure 4.7 and Figure 4.8 show a change in the frequency a barrier is mentioned. The largest change between the two figures is the jump in parameters from the 8th most commonly mentioned and discussed barrier, to the 2nd most mentioned and discussed barrier. This discussion will focus on the most problematic barriers, and their effect on the adoption of CTs in the United States.

### 5.3.1 Psychological

The psychological barrier to adoption is the most problematic and difficult barrier to overcome in the adoption process. Psychological aspects include the public perception, thoughts and mental states affecting behavior towards the use of a CT. The two forms of psychological barriers found were negative image association, and cultural influence.

5.3.1.1. Image

In the field of innovative technology, image is highly influential (Kleijnen, de Ruyter, & Andreassen, 2005). According to Ram (1989), the image barrier is formed through problematic perceptions derived from lack of knowledge and dominant stereotypes. Since a technology such as the CT is so far from being the standard of waterborne toilet systems, potential adopters must take a social risk to adopt the technology. The future if CTs as a standard in homes and enterprises is an unsure future. Potential adopters experience difficulty judging whether or not it is a wise decision to adopt an innovation like the CT (Kleijnen, Lee, & Wetzels, 2009). The image of the outhouse is still strongly associated with dry sanitation methods such as the CT. Many Americans have experience with camping or an event using port-a-potties that emitted strong odors. Even though the technology and aesthetics of CTs have improved, some stakeholders felt that the there is still a lack of desire, and a lack of ability to see benefits composting toilets soil benefit.

Discussion with stakeholders shows that slow but sure improvements are perceived in the social attitude towards CTs in the US. The 47.01% of participants who felt that composting toilets had become more accepted and seen in positive light by society attributed much of this to the focus on sustainable practices, and the slow realization that resources such as fresh water are limited.

5.3.1.2. Culture

M. Solomon, Bamossy, and Askegaard (2002) define culture as "the accumulation of shared meanings, rituals, norms and traditions among the members of an organization or society." Cultures can have a profound effect on the choices made by potential adopters. In a stronger culture, deviations from traditional norms and practices may be seen as a negative choice, and discouraged.

In Western cultures, the perception of handling human excreta is dependent on the specifics of use, and the culture of the respondent. The topic of a privy or composting toilet often elicits humorous responses or unease, however discussion of a central sewage system is more accepted (Warner, 2004). The reaction of each culture gives insight to the level of faechophilic (high acceptance of handling human excreta) or faecophobic attitudes (fear of handling human excreta).

The US is home to many cultures spanning across the different states and regions. In discussion with stakeholders in the interview process, perceptions about the more accepting areas of the US arose. Organizations and educational experiences are more prominent on the East and West Coast such as Recode, Greywater Action, the Bronx Zoo EcoRestroom, and national parks towards the East and West. It is possible that similar, accepting cultures are across the States in agricultural areas and sustainably-conscious societies, but other areas in the States were not mentioned by stakeholders.

### 5.3.2 Parameters

The topic of parameters is another complicated barrier in the adoption of composting toilets was a common theme found in data analysis. Specifically, there are a lack of parameters in the industry of CTs to guide proper installation and project management. For this research, the term parameters as a code includes the definition, design and operation, and purpose of a composting toilet.

#### 5.3.2.1. Definition

The first structural parameter to improve the adoption of composting toilets is a standard definition that is agreed upon by the regulators and expert stakeholders of the composting toilet community. The data analysis shows that there are holes when it comes to defining composting toilets. The definitions provided by the stakeholders as well as the definition provided by the EPA show a lack in mentioning the three basic aspects of a composting toilet; the design, the composting process, and use of end-product. These three aspects provide a basic framework from which a definition provides boundaries. These parameters allow unique additions to a definition depending on a model or purpose. For example, the definition of a composting toilet meant to safely break down excrement and urine, combined or separate, using little to no water for the sake of sustainable resource use would have a vastly different framework than a composting toilet meant to provide compost for an ornamental flower garden using the deposits of a family.

The EPA definition of a composting toilet is incomplete. It lacks necessary detail the main focus of a CT; the composting process. If the end-product of a CT is to be a safe, sustainable soil amendment, then the definition should include what is arguably the most important step in CT use. The terminology used in defining a composting toilet contains common misnomers that a majority of the stakeholders would change if given the chance. The use of the word composting in the name composting toilet is not always reflective of the product sold to consumers. Some models are only a dehydration chamber for organic deposit in order to decrease volume and dispose of safely. If the toilet is not designed or used to create compost, it is not a CT.

Aside from the nonspecific use of "composting" in the definition, the term "excrement" used within the EPAs definition does not reflect common models that mix both feces and urine in the same tank to create compost. Technically, excrement is poop. Medically, excreta are both. The distinction of these two terms is an important distinction when defining composting toilets and understanding different designs, as certain models emphasize urine diversion, while others do not.

5.3.2.2. Design and Operation

Currently, CTs do not have many standard design parameters. CTs can range from a normal-looking toilet attached to a large tank such as a Clivus Multrum, to a bucket placed under a toilet seat. Both options can achieve their designed purpose, and both can be considered a CT. Basic design requirements include that "the toilets are required to have a toilet seat and a riser as well as continuous ventilation to avoid any odor issues. Other general statements (include) the composting tank design requiring sufficient volume for accommodating the people served (Anand & Apul, 2014) ." Other than these basic requirements, little is published in the form of design parameters.

#### 5.3.2.3. Purpose

The purpose of a toilet is central to an accurate definition. If the goal of using a composting toilet is to create compost, then the basics of the composting process and compost product are necessary components of the definition. If the user merely wants to use a sustainable, waterless toilet, then the toilet is a method of dry sanitation; not a composting toilet.

Depending on the purpose of an ecological toilet such as a composting toilet, there are differences in key processes and the knowledge required of the processes. Though "composting toilet" implies a toilet that composts material, different understandings exist of where, and if, composting takes place. Three participants strongly voiced that the composting process is rarely successful in certain composting toilet models, nullifying the term "composting" in the name of "composting toilets". Certain commercial composting toilets focus on the dehydration of excreta, or separation of urine from excrement at the time of deposit. To some stakeholders, this differentiation polarizes the community because the product being sold promises compost, but does not produce the safe, sanitary compost that is expected.

### 5.3.3 Codes and Regulation

Codes and regulation are a part of the approval, implementation, and lifecycle CTs. This barrier to adoption includes is met in the lack of representation, standardization, and support in plumbing codes, building codes, and the information used by writers of legislation to understand CTs. Stakeholders understand that the current codes and regulations are in place with the intent to promote the best, sanitary practices of public health. However, the codes have not adapted in recent years to better accommodate or promote waterless waste management projects. The barrier of codes and regulation to the adoption of CTs in the US is divided into three main concerns; inconsistency in nation-wide regulation, lack of knowledge in legislation, and approval of compost use.

#### 5.3.3.1. Inconsistency Among Levels of Legislation

The inconsistency of legislation of CTs across the States is a combination of varying levels of knowledge and motivation to include supportive legislation for CTs. "In the U.S., the regulations were developed by counties, municipalities and state departments of environmental quality and show some variation as well as a general lack of detailed guidelines (Anand & Apul, 2014; Jenkins, 2005)." Some states are more lenient, while many have more restrictive laws or absence of any legislation on the topic. One stakeholder in the process of approving a CT in an educational building in a rural location is experiencing little push back with the implementation, but confusion and inexperience with approaching the topic.

The responsibility of regulating CTs can be misunderstood on multiple levels of legislation. CTs are regulated by the Department of Health, local watershed authorities, and Departments of Environmental Conservation or Protection. Each of these groups has overlapping but sometimes competing claims to health and safety and so their individual policies can create conflicting types of advice and practice. This inconsistency in regulation from many factors creates dissonance and misunderstanding of CTs. On the federal level under the Standards for the Use or Disposal of Sewage Sludge (Title 40 of the Code of Federal Regulations [CFR], Part 503), a "regulation to protect public health and the environment from any reasonably anticipated adverse effects of certain pollutants that might be present in sewage sludge biosolids (United States Environmental Protection Agency (US EPA), 1994)." Part 503 was published in the Federal Register (58 FR 9248 to 9404) on February 19, 1993, and was put into effect on March 22, 1993. The Part 503 standard includes "general requirements, pollutant limits, management practices, operational standards, and requirements for the frequency of monitoring, recordkeeping, and reporting (United States Environmental Protection Agency (US EPA), 1994)." This standard is an optional program, and not required at the state level. Some states have different regulations that are more restrictive, which creates complications for a potential adopter to which state or federal rules to follow.

5.3.3.2. Knowledge of Policy Makers and Regulators

The lack of knowledge in legislation permitting and regulating CTs stems from the limited experience with CTs, perceived importance of the topic, and quality of knowledge held by the legislation writers. Though 83.3% of participants had used a composting toilet, the regulators that were interviewed had not used a composting toilet. Of the two regulators interviewed, one had in-depth knowledge of CTs, and their adoption process in the US. Neither regulator held a negative attitude towards CTs, and offered full support in the data collection process. Their attitude regarding composting toilets was positive and accepting of the progress of composting toilets, but both had yet to use one in their line of work. From the attitudes of the regulators of composting toilets and their understanding of composting toilets, their lack of personal use did not create a negative impact on their regulation of composting toilets. The state represented from the regulators showed more legislative acceptance of CT projects, and understanding of the process to implement and maintain the toilets long-term. For many states, this amount of knowledge is not the case. Resource availability, sustainability values, and CT project presence play large roles in developing what regulators must know about dry sanitation methods such as CTs. These factors are also largely connected to the geographic location of the state, the politics, and culture of residents.

5.3.3.3. Use of Compost

In addition to the inconsistent legislation of CTs and poor understanding in codes and regulation, the collection and use of the compost product lacks structure and scalability necessary to improve adoption in the US. As discussed previously, the allowance of CTs and produced compost is complicated, confusing, and can be a tricky process to maneuver depending on the congruence of local, state and federal legislation. Biosolids from wastewater treatment have been used in "agricultural crops, fertilize gardens and parks and reclaim mining sites" across the States (United States Environmental Protection Agency (US EPA), 1994). Though rare, use of excreta to enrich certain properties in the US exists.

Currently, the brunt of responsibility to push for the greater use CT product is the consumer. Demand starts the process of change for CTs, and the purpose of a CT is largely denied to be used in many areas of the US. According to Part 503, "A person must apply for a permit covering biosolids use or disposal standards if they own or operate a treatment works treating domestic sewage (US EPA, 2012)."

The requirement of permits and testing of composted product is in place for the right reasons and precautions, but the process to obtaining a permit and test all material is difficult for the average American to accomplish. This is easier to approach as a community, still placing the primary responsibility on the consumer.

## 5.3.4 Infrastructure

The infrastructure necessary to support the adoption of CTs into the US is a topic greater than this research can adequately cover. Some topics have been partially covered in other related sections, but will provide greater understanding. The aspects learned from the interviewing process provide an introductory view into the infrastructure change needed, but further research is required to full understand each element. As discussed in the data summary, the infrastructure that is required for successful CT projects is a combination of financial support, political support, maintenance and product services, and provision of incomplete services such as end-product collection.

#### 5.3.4.1. Incentives for Adoption

Currently, the only incentives for adoption are philosophical, or in completion of sustainability certifications such as LEED. “Arguably, the largest incentive for adoption of an innovative technology is financial aid from an invested party, or government funding. Funding is available for sustainable research, energy conservation, alternative fuels, and collaborative efforts for a sustainable future, but composting toilets are not commonly funded. Funding is more commonly granted in rare cases where CTs are solutions to construction limitations or to fulfill LEED certifications. Composting toilets are recognized by the US Green Building Council (USGBC) and they have been used to achieve LEED certifications (Anand & Apul, 2014).” Institutional funding is a necessary step in progress to promote the adoption of CTs.

#### 5.3.4.2. Incomplete Services

The services necessary to aid the average American in adoption of CTs are limited and incomplete.

Manufacturers and promoters of CTs within the US are the only possible source of service provision. One of the top providers of CTs, Clivus Multrum, outlines there service provision on their website: “Clivus offers maintenance services to all its customers, ranging from complete system maintenance to periodic inspection and reporting. In locations beyond our immediate service area, Clivus provides maintenance through local subcontractors (Clivus Multrum, 2010).” This support depends on the distance from the nearest Clivus Multrum establishment or subcontractor. Similar claims can be made of waterborne systems in rural locations, but a larger network with more knowledge on the topic is still available for users of the waterborne system.

If a composting toilet is to stay true to its name, then a successful, sanitary end-product must be consistently produced and able to be used or distributed. Without supporting a wider range of services to aid adopters in the lifecycle maintenance and transportation of composted material, adoption cannot reach full potential.

5.3.4.3. Economic Gain

The adoption of CTs into the US lack two types of economic gain; the ability capitalize on profits from selling produced compost, and the competition with the current waterborne system financed by the US. If a successfully implemented project produces sanitary, consistence batches of compost, the uses for the compost has profitable potential. According to Part 503, "biosolids may be composted and sold or distributed for use on lawns and home gardens. Most biosolid composts are highly desirable products that are easy to store, transport and use (United States Environmental Protection Agency (US EPA), 1994)." Though it would seem this regulation lays the groundwork for state adoption of economic gain of the compost, stakeholders felt that market regulations were not developed to the point of allowing the use and selling of biosolid compost. With this barrier, demand for CTs and produced compost cannot grow.

Composting toilets meet economic and professional resistance such as the distaste for another type of waste disposal system that does not include the subsidized system of pipes and waterborne toilets. The full price of adopting a CT suffers a dual expense due to the requirement of paying for a septic connection as well as a commercial, certified CT. The full cost of a CT is internalized by the consumer. If consumers pay taxes to maintain septic systems and pay a subsidized cost for use of a septic system, then the consumer has less drive to choose an additional toilet solely to be sustainable or responsible. Without government support on a nation-wide scale like the current system, and difficulty in profiting from composting, the effort of adoption meets a difficult barrier in economic terms.

### 5.3.5 Lack of Knowledge

The knowledge of CTs was analyzed between two different groups; the stakeholders and the average American. The knowledge of regulators was discussed in the barrier of codes and regulation. As a result, this section will focus on the lack of knowledge of the average American of CTs. This evident lack of knowledge and awareness is not a negative reflection on Americans or CTs, but an indication that education is required across the States to create awareness. The majority of stakeholders fulfilling roles as educators show that there is education available on the subject, but their collective perception of the average Americans knowledge suggests the widespread of that knowledge is slow. The most likely form of knowledge the average American has is experiential; using a CT or in a state park or camping site. Without exposure to successful CT projects or education, the average American will maintain a negative image of CTs.

### 5.3.6 Cost

Initially, literature showed a possibility of long-term savings from the implementation of CTs. This was not mentioned by stakeholders when discussing cost. Instead, discussion led more to the idea that there was little economic difference between the two implementation choices. This view is disagreed with by past research (Anand & Apul, 2014; Jenkins, 2005), but defended by different stakeholders in this research.

In some situations where constructing a septic system is dangerous or harmful to a delicate destination, CTs are able to provide long-term cost-savings. If a connection to a septic system is not required by law, the purchase and use of a CT is permitted, and there is room to compost and maintain the toilet, a CT can provide cost-savings in more than delicate destinations. However, this is not a common set of circumstances.

## 5.4 Differences and Similarities of Adoption in Urban and Suburban Locations

After approaching the topic of overall adoption of CTs into the US, questions were narrowed to focus specifically on the similarity and differences of these barriers between urban and suburban locations.

### 5.4.1 Similarities

The 82.3% of stakeholders who felt that the same barriers were experienced in urban and suburban locations emphasized four similarities between the two location types; required codes and regulation, dependence on building infrastructure, lack of collection service, and lack of maintenance service.

#### 5.4.1.1. Required Codes and Regulation

The codes and regulation between urban and suburban locations was perceived to be largely the same. The discussion of codes and regulation differing between urban and suburban locations begins in discussion of the difference in implementation and impact of the legislation.

5.4.1.2. Dependence on Building Infrastructure

No matter the location of a CT, the building infrastructure housing the CT plays a key role in design and maintenance. The number of building stories in a house matter just as much as the number of building stories in a commercial enterprise in an urban setting.

5.4.1.3. Lack of Collection Service

The need for a collection service with a similar set up to that of a recycling program is absent in both urban and suburban locations. Though suburban locations are more likely to be close to spaces that may accept or dispose of toilet contents, a service to support the management of CT end production for all location types is missing.

### 5.4.2 Differences

There were three noticeable differences in the ways barriers are experienced between urban and suburban locations; space availability, options for fertilizer use, and the impact of codes and regulations.

5.4.2.1. Space Availability

The large majority of stakeholders perceived the same barriers were present between urban and suburban locations. The effect of the barriers creates the differences in adoption rates of these location types. When discussing which sites would better support adoption, the most common response referred to the location with the most yard and housing space. Specifically, the ideal space allowed enough room for larger CT models, close access to a yard or garden to use compost, and no more than two floors per building. It is possible for a residential space in an urban and or suburban location to have the same space. However, it is more common for an urban building to have multiple floors with dense populations. A building with more than two floors is an uncommon project due to the amount of people living on multiple levels creating large amounts of excreta and requiring a larger network of pipes. Excreta would be amassed on a greater scale, stressing the availability of sanitary storage, proper aerobic conditions, and the collection of the composted material.

For urban locations, the population can be more removed from agricultural experiences and processes such as composting. The space type residents live in strongly influence their psychology and behavior towards CTs. Strong oppositions can arise from issues regarding expectations of sanitation. Residents of urban spaces are more likely to be removed from hands-on experience with agriculture, botany, or any form of maintaining natural processes. Though the same barriers exist in adoption into either location type, the psychology of urban dwellers differs from that of suburban dwellers.

#### 5.4.2.2. Options for Fertilizer Use

The use of domestic biosolids in the composting process limits the locations for potential use. Once the material is collected, use of domestic biosolids in urban areas is more limited than suburban options. Though not ideal, CT adopters in suburban locations can collect their own material and create compost in their own backyard for personal use.

#### 5.4.2.3. Impact of Codes and Regulations

The use of CTs in suburban locations can go unnoticed depending on the use and maintenance of the user. This route is not suggested or encouraged by this research, but a resident in a suburban location may have more freedom in the implementation and long-term maintenance.

## 5.5 The Path to Success or Failure

Across the United States, the adoption process is in different stages. With successful implentation at the Bronx Zoo, a strong case can be made for potential adoption success. The Bronx Zoo allows high relative advantage, low complexity, acceptable compatibility, high trialability, and high observability. The Bronx Zoo provides positive image reinforcement combatting misnomers of CTs with easy-to-use public restrooms. Using the restroom becomes an educational experience, also providing healthy compost for the property. This successful implementation also provides developing or potential projects with a case to study.

Early adopters have implemented CTs into their communities as a grassroots movement along the East and West coast in the US. These projects have branched from necessity of waste management without connection to a septic system, to voluntary community mandates to protect bodies of fresh water (A. Cordova, personal communication, 2014; L. Orlando, personal communication; 2014). With new projects on the rise on the coasts of the US, and sustainable practices and regulation budding on the West coast such as Recode, it is possible to see adoption still progressing. However, are these projects enough to put CTs on the path to successful adoption? The analysis of CTs as an innovative technology showed that to the average American, the technology showed little promise of appeal. The best chances of success will remain with public facilities with the resources to build and maintain projects with previous successes as guides.

Until literature stops selling that promote the building and purchasing of CTs, and companies such as Clivus Multrum are no longer in business, it is safe to say the adoption process has a chance to succeeding on a greater scale. It is also possible that CTs may never expand from small, environmentally-minded communities looking to do their part for the environment. This thesis cannot determine the future of CTs, or the possible result of adoption of CTs into use in urban and suburban locations in the US.

## 5.6 Stakeholder Suggestions

The scope of this research did not include making suggestions to better the adoption process or overcome barriers to adoption. However, with a purposeful sample of stakeholders with vast experience and knowledge, desired changes and insightful suggestions were communicated in every interview. This section was shaped by the thoughts of stakeholders and their suggested actions to strive for a successful adoption of CTs into urban and suburban locations in the United States

### 5.6.1 Adoption Process Improvements

The results of this question are in the discussion only due its focus on what can be done about overcoming barriers instead of the barriers to adoption alone. In total, 26 responses were listed, resulting in 10 common themes. This question focused on the future of bettering the adoption process, taking the concept of barriers and extending it to include actions considered necessary to the stakeholders after discussing the barriers to adoption.

"*What must be done in the adoption process to allow increased size of composting toilet projects?*"

Each action listed is based on the previously listed barriers, and furthered with the actions described by stakeholders:

- Infrastructure - Dry sanitation strategies such as CTs must have support and an understanding of dry sanitation as formal part of the repertoire of sanitation options. Service support, collection and management of end product are required to build a successful infrastructure. Composting toilets must be part of government strategies and plans. One of the largest issues of infrastructure is viewing CTs as a unit versus a system. The barriers to implementing one CT vs a system are different, and can be costly. What are ways that government or public funds could assist for ecological integrity?

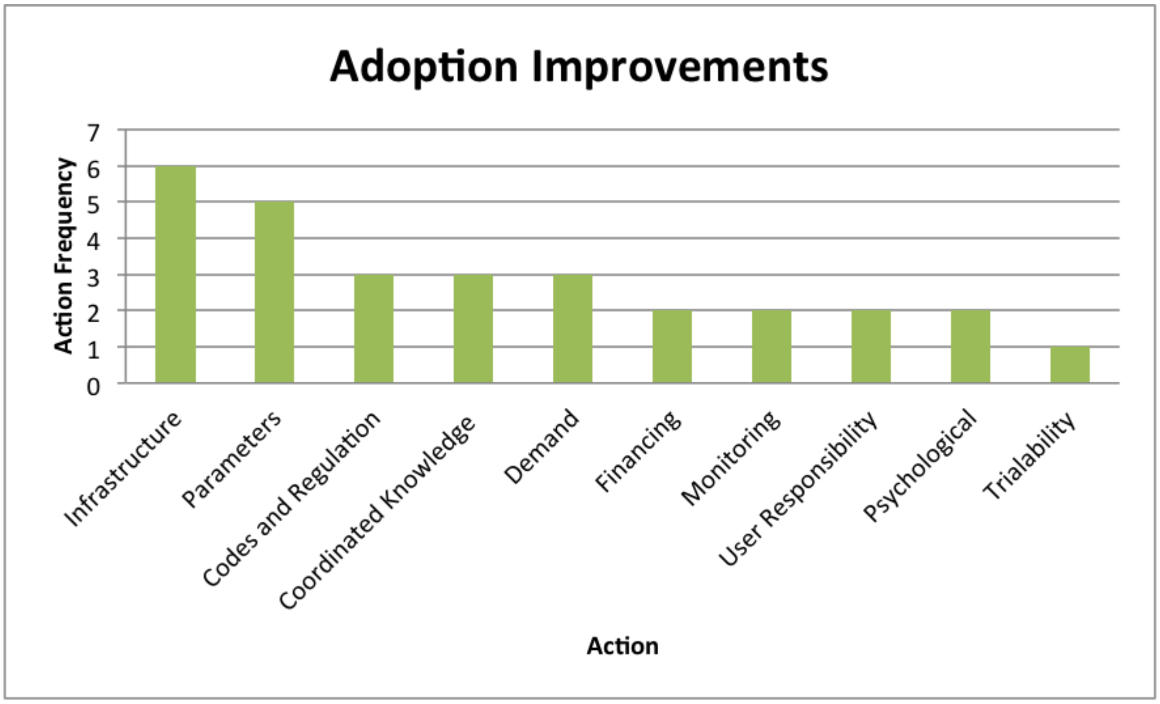


Figure 5.1. Actions to Improve Composting Toilet Adoption

- Parameters - Parameters that are needed to improve the adoption process of CTs range from design requirements to realistic expectations of CTs. Adoption of CTs requires the understanding of what space is required to build certain models, and how to build when there are multiple building levels. Parameters must include standard definitions of common terms, design aspects, and the purpose of implementing a CT. When projects are successful, the parameters of the project should be published or shared, proving and providing successful parameters to regulators and potential adopters.

- Codes and Regulation - The legislation that regulates and determines implementation lacks in appropriate knowledge and open-mindedness of innovative, sustainable on-site water treatment systems such as composting toilets.

- Coordinated Knowledge - There is a knowledge gap that exists between all groups that would need to be involved in a project implementing composting toilets. This gap must closed as much as possible for each project to the point of knowledge required being easily accessible knowledge for contractors, architects, plumbers, etc. Coordinated knowledge also refers to the increased awareness and knowledge of sector professionals such as the stakeholders targeted for this research.

- Demand - Demand can fuel the adoption process of CTs by formalizing dry sanitation methods as mainstream.

- Financing - Public and government financing must be present, and have to go beyond projects. This financing must be part of strategic investments, building a future for CTs.

- Monitoring - A monitoring system available for more CTs would be able to understand the current stage of the compost. Monitoring does not only including CT systems, but also observing and communicates the harms of how the current, waterborne systems are slowly breaking.

- User Responsibility - Users must adapt to the long-term responsibilities to maintain the health of the composting process, as well as collection and management of end product.

- Psychological - Steps must be taken to change perceptions of CTs to change the behavior of the public. This involves attempting to change the perception of sanitation, and the benefits of taking control of personal waste.

- Trialability - Finding better ways to trial CTs introduces the technology on a less threatening level, and shows the possibilities of odor-free on-site waste treatment. The maintenance required can be practiced and approached before purchasing.

### 5.6.2 Overcoming Barriers

Barriers to adoption of an innovative technology can be approached, and ideally, overcome. Stakeholders understood the odds stacked against CTs in their path to adoption, and the needed changes to give the best chances of success. The following barriers listed are coupled with suggestions made by stakeholders to show may be done to overcome the barriers.

#### 5.6.2.1. Psychological

The image of composting toilets is the most approachable aspect of the psychological barrier to adoption. It takes a strong, positive example of using a CT to overcome concerns and misconceptions. It would take more successful CT projects in the US such as the Bronx Zoo to provide well-packaged, educational experiences to large populations to improve CT image. This image change must also be more influential than the negative experiences across the US.

One of the best hopes for the enhanced adoption of CTs in the United States is the improvement of attitudes towards the concept. "Experts in ecological sanitation note that when people see for themselves how a well-managed system works, most of their reservations about handling human waste disappear (Warner, 2004; Winblad, 1998)."

#### 5.6.2.2. Parameters

The parameters outlined from earlier in the discussion were the definition, design and operation, and purpose of CTs. Suggestion improvements were given for the definition and design and operation.

A standard definition that encompasses the basics of all composting toilets would provide a common structure from which deviate depending on the toilet models difference. A definition that more experts agree on and commonly reference would put some of the most important figures onto the same page, and focus the efforts of the right people on the right objectives; the betterment of the technology and education of CTs.

Issued standard parameters for different situations and purposes provide better guidance for volume, aerobic conditions, maintenance of substrate, organic additive material, and whether or not to mix feces and urine in the same holding container. In research by Cordova and Knuth (2005) investigating the barriers to adoption of CTs in Mexico, design issues and material decisions also affected aesthetics and comfort, which in turn influenced user acceptance and satisfaction with the toilets. Though a different population and culture was the focus of Cordovas research, the importance of design in the acceptance and success of CT implementation may be a transferrable value. Standard designs assist in the maintenance of a CTs lifecycle by different services. After the implementation of a CT, a subcontractor or cleaning service would have a deeper understanding of what layout to expect, and provide better service.

#### 5.6.2.3. Codes and Regulation

The aspect of codes and regulations that were coupled with suggestions was the inconsistency of knowledge among different levels of legislation.

If a standard body of knowledge were to be construced and consistently used by stakeholders of the CT industry, this body of knowledge may be proven and used by the levels of legislation. One standard body of knowledge with proven success can give policy-makers and regulators peace of mind that the literature provides safe practices for citizens. If CTs are to succeed, the individuals writing plumbing codes, building codes and state legislation must have a standard body of knowledge to reference and learn from.

5.6.2.4. Infrastructure

The incomplete services to support the adoption of CTs by more people was highly discussed by stakeholders. If a household ware such as a washing-machine, heater, water pump, or waterborne toilet required maintenance, the homeowner would have multiple choices of service-providers to provide assistance. The service-providers would compete in a similar market, each having knowledge of the system to be serviced. These types of services as well as collection of composted material are not as readily-available for CTs.

Adoption of CTs into the US would flourish with a collection services comparable to the collection of recycling. This limitation is understandable in light of potential health hazards. A collection service would insure the full composting process has been completed before the intended distribution or selling of compost in accordance with required sanitation requirements of the regulations specific to the destination. "In other words, besides water savings, which DS (dry sanitation) achieves by definition, the full promise of positive environmental impact of DS hinges heavily on end-product containment and management... Because of the critical importance and complexity of this step, end-product management research needs must be considered (Cordova & Knuth, 2005) ."

## 5.7 Limitations of Research

Through the completion of this thesis, limitations outlined in the first chapter were experienced as well as unexpected limitations. The stakeholders who chose to participate in this research did not represent different backgrounds with equal distribution. The results gathered and analyzed were enlightening and thorough, but the heavy representation of stakeholders with a role primarily in education can be viewed as a limitation of this research.

The initial thought process of collecting data included interviewing stakeholders including homeowners with CTs, and people who have never used a CT before. The original interview form contained two sections to include stakeholders with extensive knowledge as well as inexperienced stakeholders. This stretched the ability of the researcher to successfully create a validated survey or to focus the research. This limitation led to missing understanding the demographics of adopters of CTs, and understanding the characteristics of CT users.

## 5.8 Potential Implications of Research

The analysis of adoption rate as well as barriers to adoption of CTs in the US in urban and suburban locations may provide future research ideas. Future researchers may use this research in combination with the leading research used to guide this thesis to propose solutions and projects in response to the barriers to adoption of CTs. Due to the limitations of this project such as the small sample of participants, small research team, and inexperience of the researcher, certain topics noted in previous research were not able to be discussed in adequate detail or length.

Such topics include:

- Program operation in successful and failed CT projects
- User perception of CTs and reasons for user acceptance

The further studying of CT adoption into the US in different locations may provide insight into the best way to adopt CTs, who to target to implement a project, and the most efficient path to gain all the required permits for operation. The right background of a future researcher may begin the proposal of standard parameters, or solutions to different aspects of necessary infrastructure for the national adoption of CTs into the US.

In an interview with Shelia Klinker, a member of the Indiana House of Representatives, the idea of CTs was met with enthusiasm and intrigue. Sheila thought that more sustainable alternatives were needed to provide a better future for the state and show that sustainable, alternative life changes can be made successfully (S. Klinker, personal communication, 2014). When asked how she would approach bring CTs into her local community, Sheila quickly pulled out a booklet of fellow representatives and influential positions who could talk to the right people to start the right movements. Sheila showed that influential positions such as a state representative can be interested in CTs, and the finding the right people to talk to can create a movement for sustainable change.

## 5.9 Summary

This research has provided research formed using the literature of some of the most relevant and influential publishing and stakeholders in the industry of CTs. Though the research is limited in its extent, the original goals have been achieved. The rate of adoption was analyzed to understand a background in the slow adoption into the US. The barriers to the adoption of CTs into use in the US have been investigated and coded into seven main barriers; psychological, codes and regulation, infrastructure, parameters, lack of knowledge, and cost. These barriers were further discussed in terms of urban and suburban adoption. The similarities and differences between the barriers experienced in adoption of CT projects were outlined with insight from stakeholder responses. Finally, the potential implications of this research were suggested.

# LIST OF REFERENCES

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